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***2008 Annual Report of Northern Pine Snake  
Management and Conservation at Stafford Business  
Park, Stafford Township, Ocean County, New Jersey.***

Pinelands Application No. 1986-1159.029



*November 6, 2009*

*To*

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## INTRODUCTION

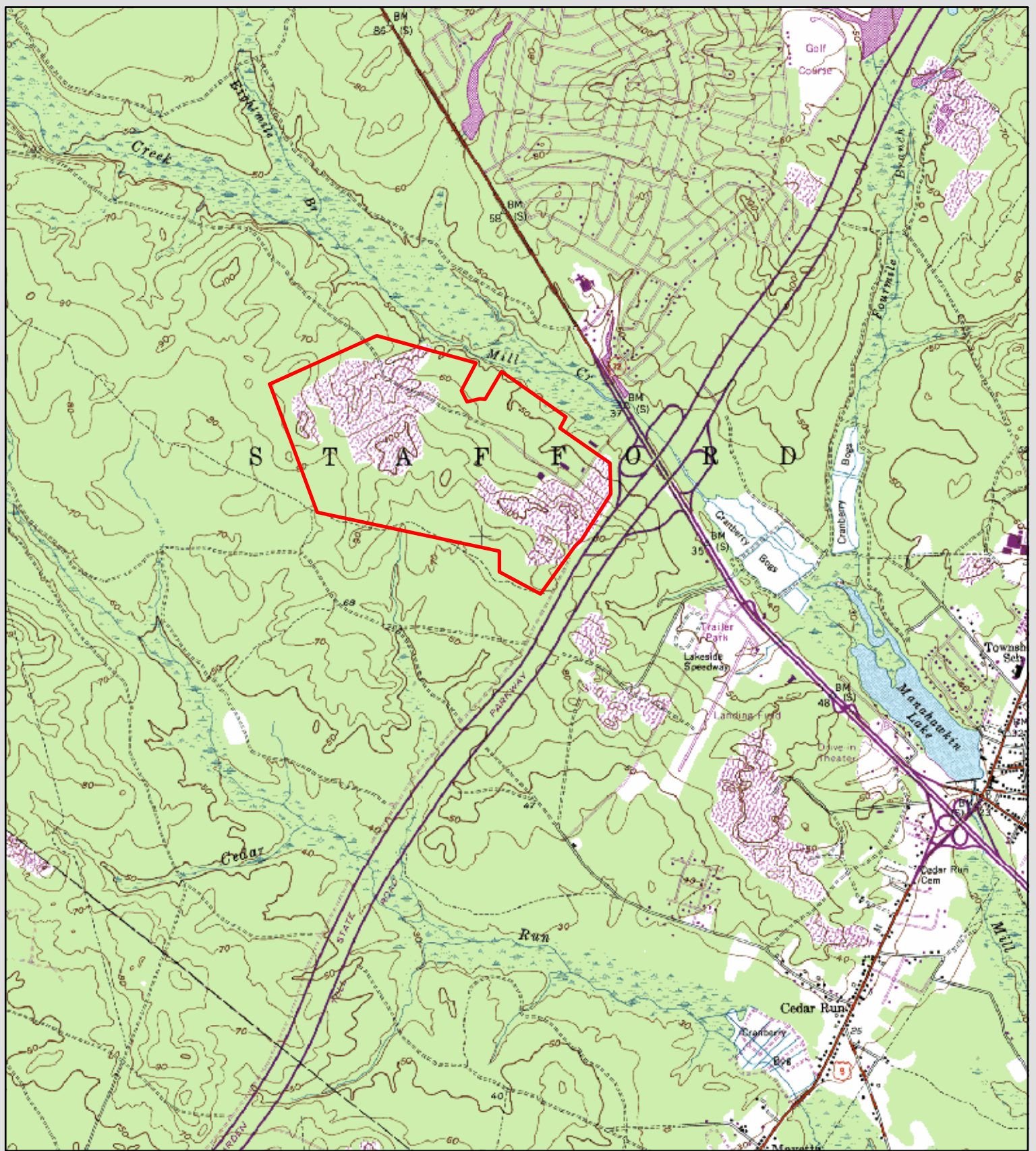
This is the second annual northern pine snake (*Pituophis m. melanoleucus*) progress report with respect to the June 28, 2006, “Memorandum of Agreement” (MOA). The MOA was made between Walters Homes, LLC (hereafter Walters), Stafford Township, Ocean County and the New Jersey Pinelands Commission (hereafter the Commission). As part of its responsibilities for this development, Walters has agreed to build a new legal landfill on the redevelopment site to replace the old one that was polluting Mill Creek. The new landfill would be sealed and capped with warm season grasses. Walters also agreed to create three (3) pine snake habitat management fields, containing six (6) artificial overwintering hibernacula (hereafter dens); shift a portion of the population of pine snakes; and initiate a seven (7) year pine snake monitoring program. Walters has completed the remediation of two old landfills and the construction of a new legal landfill. This is the first phase of the proposed commercial and residential development known as Stafford Park Redevelopment property (hereafter SPR property) in Stafford Township, Ocean County, New Jersey (**Figures 1 and 2**). Walters has constructed a large commercial (retail) section of the proposed development and will begin residential development (apartment buildings) in 2009. The SPR property is 388 acres in size. 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 property.

## BACKGROUND INFORMATION

Threatened and endangered species surveys commenced at the SPR property on April 2004. These surveys, which were conducted by EcolSciences, Inc., revealed the presence of three (3) state-listed species, including the northern pine snake. 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.

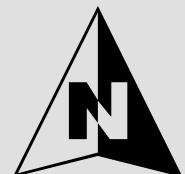
Walters was permitted to proceed with the SPR project provided that specific conditions were met regarding the mitigation of potential impacts to pine snakes, as well as other threatened and endangered plant and wildlife species. Progress reports for rare plants and treefrogs are provided by HA under separate covers. These conditions were also outlined in the June 28, 2006 MOA. 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. 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 to the Commission 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.” Outlined in this proposal were the following objectives and important questions:



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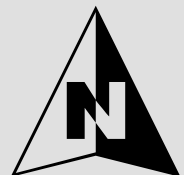
**Figure 1.** Location of Stafford Business Park in Ocean County, New Jersey.  
**Source Imagery:** USGS Topographic Quadrangle "West Creek"  
 Herpetological Associates, Inc. 2009.





0 750 1,500 3,000 4,500 6,000 Feet

**Figure 2.** Location of Stafford Business Park in Ocean County, New Jersey.  
**Source Imagery:** 2007 NJDEP Color Infrared Imagery  
**Herpetological Associates, Inc. 2008.**



## **PART I:**

The primary objective of the study plan is to protect pine snakes using the site from any direct human-caused injury that might occur during the landfill closure, remediation, and construction activities. A secondary, but equally important objective is to mitigate the loss of pine snake foraging, nesting, and denning habitat through enhancement at the Stafford Forge Wildlife Management Area (WMA). Stafford Forge WMA was selected because it borders the SPR property on three sides, is highly suitable habitat and is within the home range of the pine snake population. It is also protected by the New Jersey Department of Environmental Protection.

## **PART II:**

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. The habitat manipulation and management was provided as an alternative to replace the lost landfill habitat within the Stafford Business Park Redevelopment site.

The long-term monitoring program will address and possibly answer the following six 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 (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?
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?



## MATERIALS AND METHODS

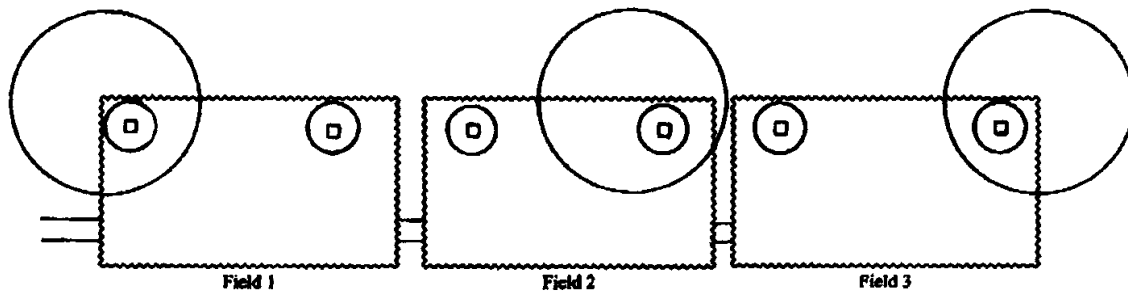
### STAFF SURVEYORS

There were numerous tasks to be performed during the 2008 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, William Callaghan, Joe Embrey, Raymond Farrell, Robert Fengya, Ted Gordon, Zigmund Leszczynski, Matthew McCort, Michael McGraw, Pete Mooney, David Schneider, Michael Zappalorti and Robert Zappalorti. Dave Golden (NJDEP), also supervised and assisted with various tasks throughout the 2008 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 removed from the SPR property. HA 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 three hundred (300) feet by eight hundred (800) feet in size (or about 5.5 acres) (**Figure 3**). These three 5.5 acre fields are meant to replace the open grassland habitat that was lost on the SPR site (e.g., the old landfill). Two (2) snake dens (artificial hibernacula) were constructed on each management field, approximately three hundred and fifty (350) feet from one another. Each hibernaculum was encircled with a one (1) acre fence to keep the snakes within the den enclosures. The circular fence stood five (5) feet in height. Three of the dens (1, 4, and 6) had a larger, three (3) acre perimeter fence for holding the pine snakes over a twenty month period (1.5 years). A total of ninety-five (95) snakes were released into the dens in the fall of 2006 (i.e., twenty (20) adults, four (4) sub-adults, and seventy-one (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, was not originally planned, but was created out of necessity after it was determined that 8 of the 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 were determined healthy enough to be released into the two-winter treatments in the spring of 2007 and were monitored via radiotelemetry through the 2007 and 2008 activity seasons. For more detailed information on all monitored snakes refer to the synopses and home range analysis section of this report. After emerging from their dens, snakes from the two-winter treatments were to be released into the 3 acre corrals. Due to complications from hawk predation and damage related to the May 16, 2007 forest fire, these 3 acre perimeter fences were no longer 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.



**Figure 3. Layout of the Northern Pine Snake Management Fields, Artificial Hibernacula and Fences at Stafford Forge Wildlife Management Area, Ocean County, New Jersey from 2006-2007. In 2008 corral walls were removed from around all artificial hibernacula.**

**Legend:** □ = Artificial Hibernaculum, ○ = 1 acre Winter Fence, ○ = 3 acre Summer Holding Corral.

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

Another portion of the relocation and management phase of the conservation plan involved habitat enhancement for pine snakes. This included the construction of six foot high earth berms along the edges of the three fields and large earth and wood debris piles within the center of the fields. These earth berms were constructed out of A-horizon sand, stumps, logs and brush. The fields provide pine snakes with forest-edge 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 soil 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**

During any habitat alteration, a qualified HA staff member was present to examine the area for any reptiles or amphibians that may be 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 forest within the property boundaries of the Stafford Park site was mostly completed in 2006 and 2007. Any pertinent data with respect to environmental monitoring will be further explained in the results section.

## HABITAT EVALUATIONS

HA has three criteria for judging the value of the existing conditions and habitat available for endangered and threatened 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 species within a specific study area (Burger and Zappalorti, 1986; Reinert and Zappalorti, 1998a and 1998b; and Heyer et al., 1994).
- 2. Historic Evidence:** Known sightings in the State Natural Heritage Program database of the target species, and historic records on or in the vicinity of a study site, are important to the overall evaluation of a site (Zappalorti and Johnson, 1982).
- 3. Indicator Species:** The presence of plant and animal species that are often found in association with a target species is highly informative when evaluating a site. Such indicator species may include food/prey organisms, or species that typically occur in similar or identical habitats as the target species. The presence of associated or indicator species demonstrates the ecological value of the habitat within a particular study site.

## 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. The following visual search methods were performed:

### *Random Opportunistic Sampling (ROS)*

A relatively simple method for the trained herpetologist, ROS was employed while other sampling techniques were being performed on the study site. Various areas which showed potential for the species of interest were searched. This search method was not constrained to standardized time or transects, but instead relied on the experience and professional judgement of the investigators. This method is effective if there are no time constraints on the survey and more detailed follow-up surveys will be performed (Campbell and Christman, 1982; Karns, 1986). Qualitative impressions were determined as to the relative abundance and habitat use of certain species during random opportunistic sampling. 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, and leaf-litter, as well as artificial cover objects such as 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. During times of the year when target species are known to congregate in particular habitats (e.g., nesting area, hibernacula) for some aspect of their life history (e.g., egg laying, hibernating) TCS is highly productive and superior to other types of surveys (Campbell and Christman, 1982; Karns, 1986).

### ***Diurnal and Nocturnal Road Cruising***

Roads which border potential habitat often yield both living and “road-killed” 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 (Karns, 1986). 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 during crossing attempts were easily collected and/or identified.

### ***Pine Snake Nest Survey***

Surveys for pine snake nests were conducted visually. Typical pine snake nesting habitat consists of sandy uplands with little or no shrub or tree cover and an assortment of 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 pile left by the nesting female during or immediately after the nesting period (Burger and Zappalorti, 1991 - **Figure 4**). Additionally, pine snake nesting can be documented by locating the new hatchlings or their fresh shed skins in early September, at a time when the effects of weather often makes characteristic sand piles difficult to identify (R. T. Zappalorti, pers. obs.). Previous critical habitat reconstruction studies (Zappalorti and Reinert 1994) have shown pine snakes using artificial den mounds and debris piles as nesting sites. In this respect, pine snakes can be occasionally opportunistic in their nest selection.

The primary goal of these surveys was to delineate critical pine snake nesting habitat. All potential pine snake nesting habitat on the study site 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 2008, searches were conducted on portions of the landfill that were prepared for capping (graded with clean fill dirt), but not yet capped. All other nest searching efforts were concentrated within Stafford Forge WMA, with emphasis placed on the management fields created in 2006. One of HA’s goals is to ultimately observe nesting within the suitable habitat created there.



**Figure 4** Pine snake 2007.05's nest in the earth berm along western edge of management field 2. Note the large dump pile in front of the entrance hole created by the snake while excavating the nest chamber. Photo by Robert Fengya, Herpetological Associates, Inc. 2008.

### ***Drift Fence Trapping***

One large drift fence, totaling approximately thirteen thousand (13,000) feet with one hundred and thirty-nine (139) box traps, was erected around the study site and has been in operation since 2006. The fence traverses various habitat types in an attempt to capture free-ranging pine snakes. The perimeter drift fence is also meant to exclude pine snakes and other species from entering the SPR property. The trap line was shut down at the end of the 2007 field season and re-opened on April 15, 2008. This technique was used in conjunction with the visual sampling techniques described above to increase the chance of capturing pine snakes. The drift fence was constructed of black nylon silt fence, three (3) feet in height, and was supported with oak stakes. Approximately five (5) inches of the fence material was buried below grade level, thereby preventing snakes from crawling under the fence. A small hole (approximately four (4) inches in diameter) was cut into the fence material at the ground surface, and a box trap was connected to the hole, thus providing a place for snakes to crawl through the fence and become trapped.

Each box trap measures approximately 3 feet long, 1 foot high and 1 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. 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 shade-board was placed over the top to provide shade and reduce exposure to the sun.

### ***Protocol for Releasing Trapped Pine Snakes and Pine Snakes Found Within the Landfill***

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 SBP site from adverse impacts and direct harm during the redevelopment process. This includes, but not 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 seven hundred 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 and PIT Tagged, then released according to the same procedure followed for radio-tracked specimens.

Snakes that were found to have accessed the landfill property, either by traveling down the management field access road or otherwise breaching the perimeter drift fence, were carried to the nearest point on the drift fence and then moved five to seven hundred feet into the surrounding forest adjacent to that point in the same fashion mentioned above.

## **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 mass. The typical 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 (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 and 2008 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.

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 interval. Equipment problems (either transmitter or receiver) also affected the tracking interval, but attempts to locate each snake were made every 48 hours. Each snake location was recorded in the field using a Trimble GeoExplorer 3 GPS unit.

### ***Transmitter Surgeries in 2008***

Snakes implanted in 2006 had their old transmitters removed and replaced in 2008. Twelve snakes were systematically collected from the field for the surgery procedure. These snakes came from all three treatments (A, B & C). HA contacted the veterinarian who originally performed the implantation surgeries to remove the transmitters. The primary reason for this was transmitter complications experienced with other 2006 snakes. Upon HA's involvement with this project, some snakes were found to have transmitters moving freely within the coelomic cavity, inside the peritoneum. It was decided that the removal surgeries be performed by the same professional that performed the implant surgeries to avoid any added complications. All twelve transmitters were successfully removed.

After transmitter removal HA staff assessed the overall health of each snake. Time frames for reimplantation and eventual release varied with the condition of each animal. Snakes with poor body weight or other health issues were rehabilitated in the HA lab for varying time periods before undergoing transmitter implantation surgery and release. While in the lab they were fed and watered until they were deemed healthy enough to be reimplanted with the new 2-year radio-transmitters. All reimplantation surgeries were successful.

### ***Activity Range Analysis***

Radiotelemetry provided the data necessary for the calculation of activity ranges for all tracked pine snakes. Activity range is defined as the area each snake used for all life history activities over the course of a season (from emergence from hibernation until ingress). Two methods were used to arrive at the activity range for each snake: 100% Minimum Convex Polygon and Kernel Activity Range.

### ***Minimum Convex Polygon Activity Range***

The Minimum Convex Polygon (MCP) method of activity range analysis has a historic prominence in the literature due to its relative ease of use. This method uses the smallest convex polygon produced by including 100% of the relocation points for each animal to calculate activity range. The outermost points 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 radio-telemetry data.

## **RESULTS**

### **DESCRIPTION OF EXISTING CONDITIONS AND HABITATS**

The 388 acre SPR property consisted 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 state-owned Stafford Forge Wildlife Management Area and the north and east by Route 72 and the Garden State Parkway, respectively (**Figures 1 & 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 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 ecotonal transition to upland oak/pine forest, and the oak/pine forest itself, is still partially existing and will remain intact, as a good portion is protected within the wetland buffer. The southern portion of the site was a large tract of upland pine forest, contiguous to the south and west with the state-owned Stafford Forge Wildlife Management Area. This forest was cleared and graded to the property line in 2007. This area has been temporarily stabilized with vegetation and awaits residential development.

The western portion of the site consists mainly of the licensed, capped landfill and an area temporarily stabilized with vegetation awaiting residential development. Approximately 25 percent of the landfill is awaiting completion of the capping process. Storm water basins and Ocean County municipal property comprise the remainder.



The eastern portion of the site is now a shopping center with chain stores (Dick's, Best Buy, Costco, and Target) and their associated parking areas. There are two storm water basins and an irrigation pond as well. The center of the site was cleared and otherwise prepared for commercial and residential development in October and November 2008. No reptiles or amphibians were observed by HA during the monitoring of tree clearing, stump removal and soil stripping in this area. HA is confident that most resident animals were collected and translocated outside the redevelopment property onto the Stafford Forge Wildlife Management Area in 2006 and 2007.

## REPTILE AND AMPHIBIAN SURVEYS

### *Visual Survey Results*

Drift fence trapping and random searching resulted in the capture of 29 reptile and amphibian species in the 2008 active season. Our survey techniques failed to document the timber rattlesnake (*Crotalus horridus*) and the corn snake (*Elaphe guttata*), in and around the SPR property and the adjacent Stafford Forge WMA. The 29 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. redbelly snake (*Storeria o. occipitamaculata*)
  9. eastern garter snake (*Thamnophis s. sirtalis*)
  10. eastern ribbon snake (*Thamnophis s. sauritus*)
  11. ringneck snake (*Diadophis p. punctatus x edwardsi*)
  12. eastern worm snake (*Carphophis a. amoenus*)
  13. rough green snake (*Opheodrys aestivus*)
  14. eastern hognose snake (*Heterodon platirhinos*)
  15. northern black racer (*Coluber c. constrictor*)
  16. northern pine snake (*Pituophis m. melanoleucus*) (state-threatened species)
  17. eastern kingsnake (*Lampropeltis g. getula*)
  18. redback salamander (*Plethodon cinereus*)
  19. northern red salamander (*Pseudotriton r. ruber*)
  20. four-toed salamander (*Hemidactylium scutatum*)
  21. Fowler's toad (*Bufo fowleri*)
  22. northern spring peeper (*Pseudacris c. crucifer*)
  23. Pine Barrens treefrog (*Hyla andersonii*) (state-threatened species)
  24. northern gray treefrog (*Hyla versicolor*)
  25. southern gray treefrog (*Hyla chrysoscelis*) (state-endangered species)
  26. southern leopard frog (*Rana utricularia*)
  27. green frog (*Rana clamitans melanota*)
  28. bullfrog (*Rana catesbeiana*)
  29. carpenter frog (*Rana virgatipes*)
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### ***Drift Fence Survey Results***

Drift fence surveys began on April 15, 2008. Traps were checked along the drift fence once within every 48 hour time period throughout the active field season as dictated in the aforementioned management plan. There were a total of one hundred and thirty-four (134) traps along approximately thirteen thousand (13,000) feet of drift fence. Closing of the traps for the winter was accomplished on October 31, 2008.

The purpose of the perimeter drift fence is to prevent animals (specifically pine snakes) from entering the construction site and to capture any snakes trying to leave the site. During the course of the 2008 field season, twenty-two (22) species of reptiles and amphibians and four (4) species of mammals were found captured in the drift fence traps. Similar to the 2007 field season, eastern hognose snake, northern black racer, Fowler's toad, eastern garter snake, and green frog were the most commonly captured reptile and amphibian species. In 2008, seven pine snakes were captured in the traps. Of the seven, four were adults, one was a 2006 juvenile, one was a 2007 juvenile, and one was a 2008 hatchling. Two of the adult pine snakes were new captures. One was a gravid female, the other was a male that was caught late in the season. This male was fitted with an external transmitter in order to determine its overwintering location. When this snake emerges in the spring of 2009, the external transmitter will be removed and the snake released at its capture location. It will not be implanted with a transmitter. The other two snakes captured were radio-tracked animals (2006.26 and 2007.15). The 2006 juvenile was from a clutch that was hatched out in HA's lab and released into AH 1 on 09/22/06. The 2007 juvenile and the 2008 hatchling were both new captures. They were PIT tagged and released at their capture locations.

### ***Radio-tracking***

In accordance with the Northern Pine Snake Relocation and Management Plan, and the Radio-tracking and Monitoring Plan for the SPR property and Stafford Forge WMA (Zappalorti and Golden, 2006), HA initiated the seven year radio-tracking study in the Spring of 2007.

In 2008, HA continued the radio-tracking study at the Stafford Park site, with a total of 24 pine snakes being tracked throughout the majority of the active field season. However, there was a period of time when several of the study animals were pulled from the field. Please refer to the transmitter surgeries section of this report for further detail on why certain study snakes were temporarily removed from the wild. Two (2) new pine snakes, one male (pine snake 2008.02) and one (1) female (pine snake 2008.03), were implanted with transmitters. This was done to compensate for two mortalities suffered by study snakes in the beginning of the year. Please refer to the individual snake synopses in this report for more detail on snake mortality during 2008.

During 2008, HA staff captured 26 unmarked pine snakes using the various survey methods previously detailed in this report. Two of these snakes were implanted with transmitters and all other snakes were PIT tagged and released at their original capture locations. Of the 17 shifted radio-tracked adult pine snakes that were tracked by HA at the start of 2008, 13 snakes (6 males and 7 females) remain alive and healthy, 3 are deceased (2 males and 1 female), and 1 is unaccounted for (female that suffered transmitter failure) as of November 2008. Of the 12 non-shifted snakes tracked from the beginning of 2008, 11 are alive and healthy (6 males and 5 females) and 1 female is deceased.

## Individual Snake Synopses and Kernel Home Range Analysis Maps

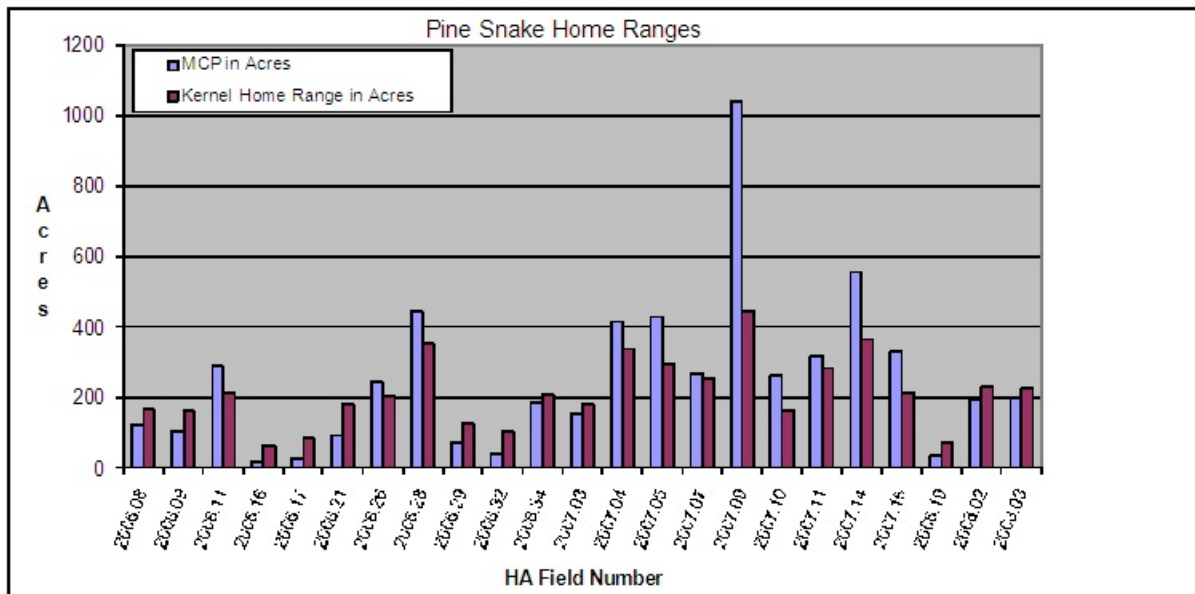
### Artificial and Natural Den Designations

Due to the identification of natural dens located by radiotelemetry in the 2007 and 2008 field seasons, all man-made dens in the management fields are hereby referred to as Artificial Hibernaculum (AH 1 through 6). All natural dens located in 2007 are hereby identified as Natural Hibernaculum (NH A through P). All natural dens located in 2008 are hereby identified as NH (Q through BB). **Appendix 1** represents each individually designated hibernaculum and the corresponding snakes that utilized them in both the 2007 and 2008 field seasons. The 2007-08 winter was the second winter that snakes were held within the two-winter treatments (AH 1, AH 4, and AH 6), thus completing the habitat imprinting portion of the study. From Spring 2008 egression henceforth, all study animals are free-roaming. Therefore, all overwintering sites used by radio tracked study snakes in the 2008-09 winter were naturally selected and unrestricted by the investigators.

### Results of Radio-telemetry Monitoring

**Figures 5, 6, and 7** show and compare the average home ranges of the shifted and non-shifted snakes, using both Minimum Convex Polygon and Kernel home range methods of analysis. **Table 1** shows the Minimum Convex Polygon home range area in acres and hectares for each individual snake radio-tracked during the 2008 field season.

A brief synopsis of every adult pine snake involved in the radio-telemetry aspect of this project in 2008, currently alive or deceased, is detailed below. **Appendix 2** provides a brief synopsis of each snake that was at one time involved in the radio-telemetry portion of this project, but was deceased before the 2008 season. Dave Golden, Senior Zoologist, of the Department has provided home range analysis maps of snakes radio-tracked outside of the corralled dens in the 2008 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 during the season.



**Figure 5.** Minimum Convex Polygon and Kernel home range analysis for all shifted and non-shifted snakes for the Stafford Business Park Redevelopment Study.

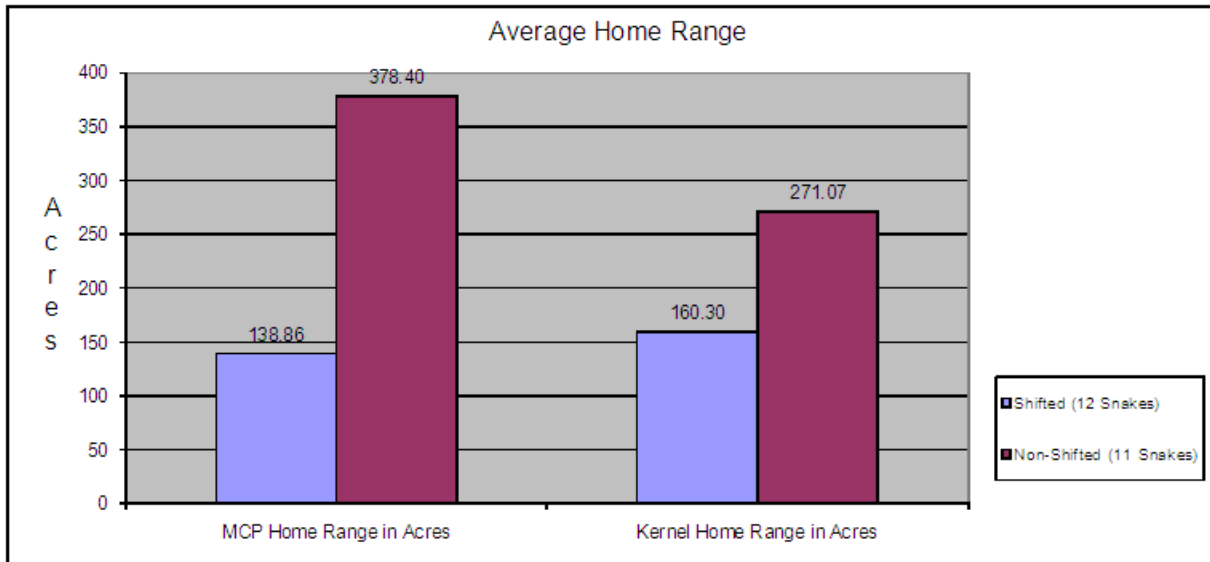


Figure 6. Average home range comparison of shifted and non-shifted radio-tracked snakes for the Stafford Park Redevelopment Study.

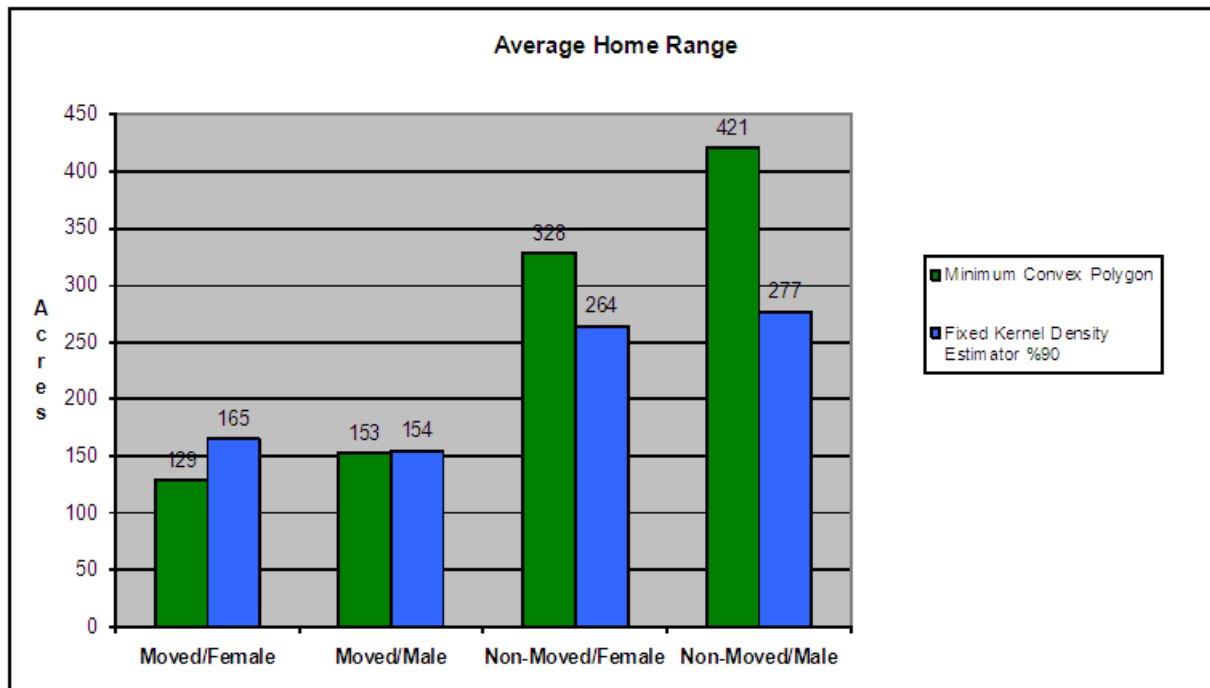


Figure 7. Average home range bisects for all shifted and non-shifted radio-tracked pine snakes for the Stafford Park Redevelopment Study.

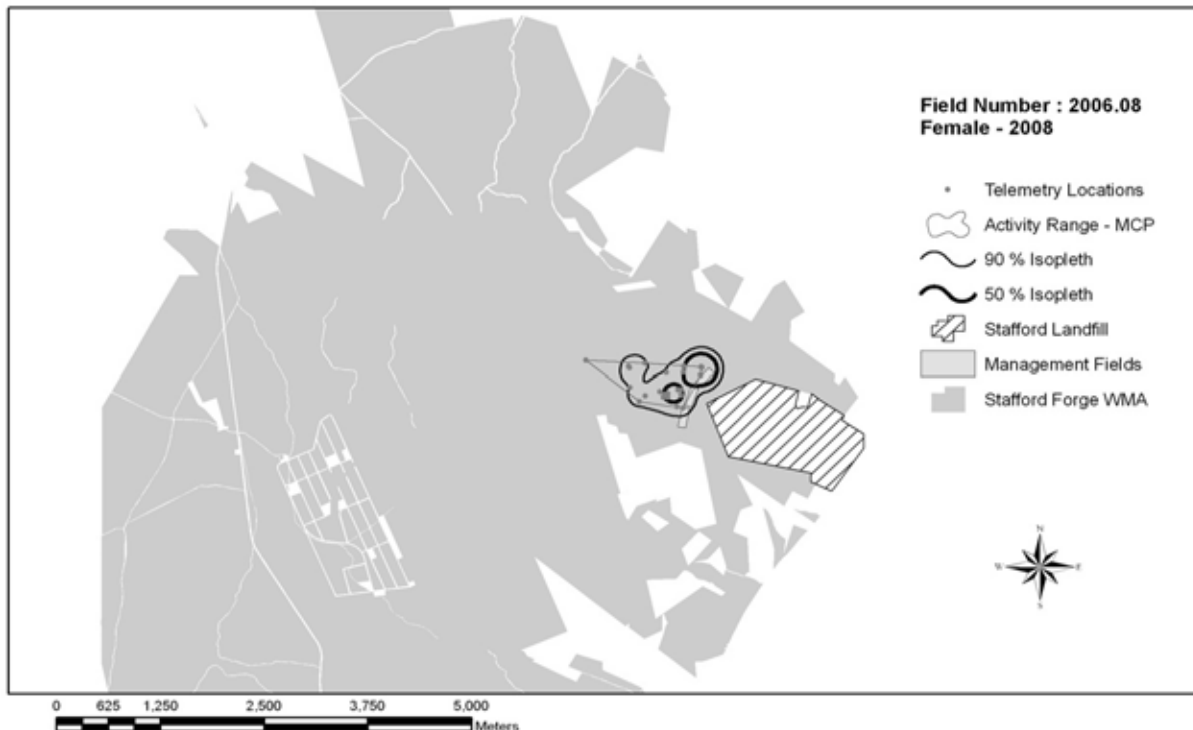
<b>Table 1. Minimum Convex Polygon (MCP) Home Range Analysis Data 2008.</b>				
<b>HA Snake Field ID Number</b>	<b>Sex</b>	<b>Number of Relocations</b>	<b>MCP Area in Acres</b>	<b>MCP Area in Hectares</b>
2006.08	F	48	120.92	48.93
2006.09	F	64	100.39	40.62
2006.11	M	49	290.94	117.74
2006.15	M	Kept in Lab.	N/A	N/A
2006.16	M	46	16.77	6.78
2006.17	M	37	27.90	11.29
2006.19	F	45	33.87	13.70
2006.21	F	49	89.61	36.26
2006.26	M	63	242.76	98.24
2006.28	F	55	444.61	179.92
2006.34	M	92	185.37	75.02
2007.03	M	87	152.87	61.87
2007.04	F	86	415.00	167.94
2007.05	F	95	426.81	172.72
2007.07	F	87	267.67	108.32
2007.09	M	75	1041.60	421.52
2007.10	M	84	262.56	106.25
2007.11	M	93	317.62	128.53
2007.14	M	38	556.65	225.26
2007.15	F	18	329.65	133.40
2008.02	F	76	193.11	78.15
2008.03	M	72	198.81	80.45

## SHIFTED SNAKES

*N. Pine Snake No. 2006.08* (♀). (Lab Treatment) Current status = alive and healthy.

**2006 - 2007:** This snake was initially captured near the landfill by EcolSciences, Inc. on 05/05/06. This snake overwintered in the HA lab (due to poor health) and was released into AH 6, a two winter treatment, on 04/03/07. On 05/01/07 it was caught in a corral trap egressing from the den enclosure and was released into the three acre outer corral. This snake was radio tracked inside the three acre enclosure until the forest fire swept through the area on 05/16/07. The snake was captured and then released back into the smaller, one-acre enclosure. On 09/07/07, HA staff found this snake's transmitter to be moving freely within the body cavity. It was collected from the den and taken to HA's lab where it was withheld over the 2007-2008 winter.

**2008:** A transmitter removal surgery was conducted on 06/01/08 and the animal was reimplanted on 07/11/08. The animal was released along the forest edge in the vicinity of AH 6. It was relocated 48 times in 2008. For the remainder of the activity season this animal frequented the upland pine forest west of the management fields. On 09/08/08, the animal concealed itself within the berm along the western edge of MF 2 while in an opaque state. On 09/15/08 the snake was located in the forest immediately west of the management fields and was observed to have recently shed. In October, the snake made a move back to the edge of the management fields and is currently overwintering in NH B, an abandoned mammal burrow located approximately 30 meters from AH 6. Pine snakes 2006.17 and 2007.03 are also overwintering at this location.

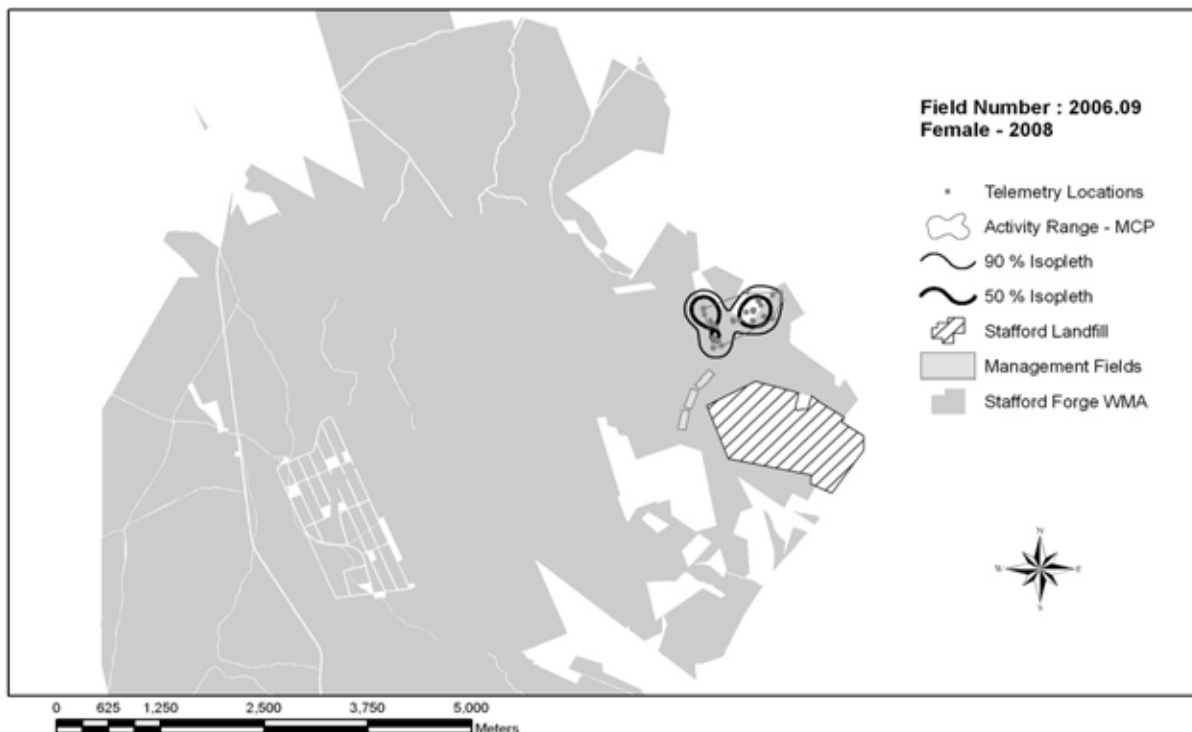


**Figure 8.** Radiotelemetry locations and activity range (minimum convex polygon and 50% and 90% isopleth from kernel analysis) for pine snake # 2006.08. The area used while being radio-tracked in 2008 is 120.92 acres (48.93 hectares).

**N. Pine Snake No. 2006.09** (♀). (Treatment A/1 winter) Current status = alive and healthy.

**2006 - 2007:** This snake was originally captured during a presence/absence survey conducted by EcolSciences, Inc. in 2004. It was recaptured by EcolSciences, Inc. on 05/09/06, implanted with a two-year transmitter, and was released on 05/17/06. The snake laid a clutch of 11 eggs in the field on 6/22/06. The eggs were collected and taken to HA's lab for incubation. This snake was released in AH 2, a one winter treatment, on 09/22/06 and hibernated there in 2006-07. The snake egressed from AH 2 on 04/25/07. It remained close to the management fields until August, 2007 when it crossed Mill Creek into an upland oak/pine forest approximately 1.1 kilometers N/NE of the management fields. It eventually selected NH I in which to hibernate for the 2007-08 winter. The entrance to this hibernaculum is a small, nondescript hole in the forest floor.

**2008:** The snake egressed from NH I on April 23, 2008. It was relocated 64 times during the 2008 field season. In May, two different male pine snakes on two separate occasions were captured within close proximity to this animal, suggesting that this female was ovulating. On one occasion a male was coiled within five (5) meters of this female. The other male was observed approximately 15 minutes after this female had been relocated on the move. It appears this male may have been following her scent trail. The snake was collected for transmitter removal surgery on 05/30/08 and re-implantation surgery was completed on 07/16/08. The animal was released into the forest at its previous location on 07/21/08. The snake spent the remainder of the season in a tract of oak/pine forest north of the SPR property. The animal 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 last season.

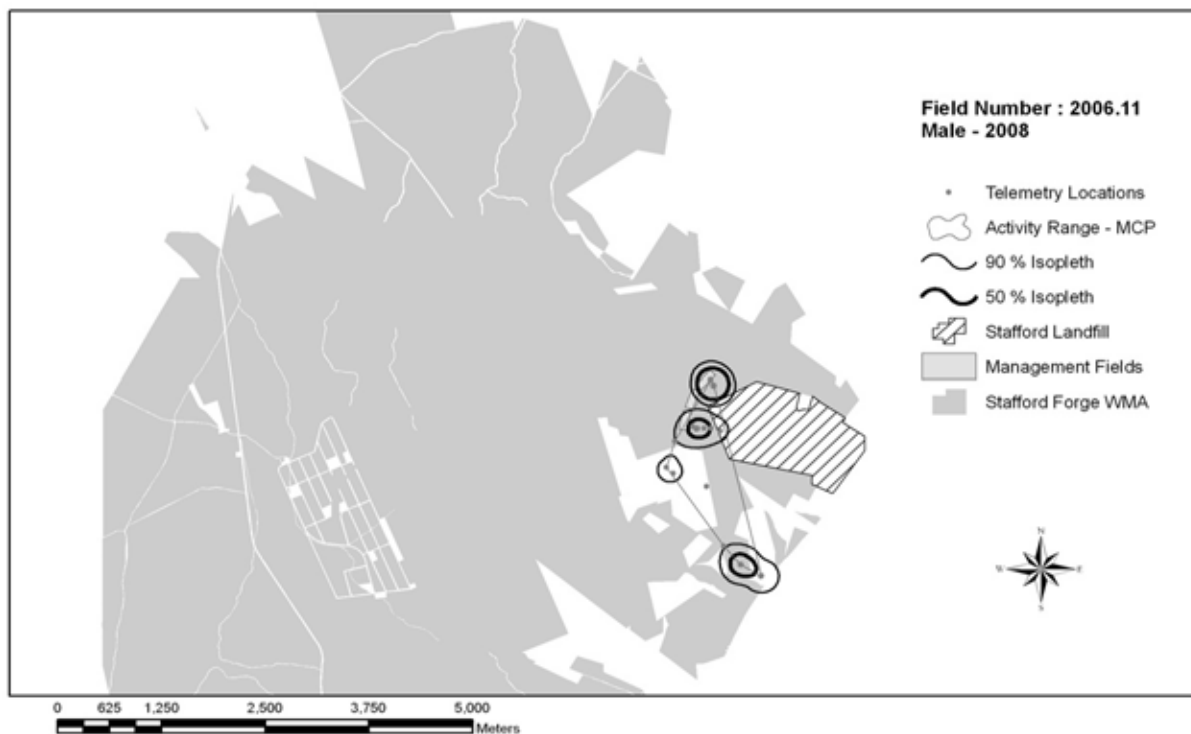


**Figure 9.** Radiotelemetry locations and activity range (minimum convex polygon and 50% and 90% isopleth from kernel analysis) for pine snake # 2006.09. The area used while being radio-tracked in 2008 is 100.39 acres (40.62 hectares).

**N. Pine Snake No. 2006.11** (♂). (Treatment A/1 winter) Current status = alive and healthy.

**2006 - 2007:** This snake was originally caught by EcolSciences, Inc. on the landfill access road on 05/17/06. It was released into AH 3, a one winter treatment, on 09/22/07 where it overwintered in 2006-07. It was caught in a corral trap attempting to egress from the den enclosure on 05/01/07 and was released into the surrounding forest. On 08/17/07 it was relocated on the Stafford Park property. It was collected from the site and relocated inside a man-made earth berm that separates Management Field 3 from the forest. In 2007-08, this snake overwintered in a natural den (NH A) approximately 75 meters SE of Management Field 3 in upland pine forest. Pine snake No. 2006.26 overwintered here as well.

**2008:** This animal egressed from NH A in April, 2008. It was collected and taken to a veterinarian for transmitter removal surgery on 05/25/08. The animal was reimplanted by HA staff and released at its last location on 08/19/08. It was relocated 49 times during the 2008 field season. Until early October, the animal stayed 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 a large and deliberate move southeast. The animal is currently overwintering 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 signs of access to underground refugia were noted in the snake's general location.



**Figure 10.** Radiotelemetry locations and activity range (minimum convex polygon and 50% and 90% isopleth from kernel analysis) for pine snake # 2006.11. The area used while being radio-tracked in 2008 is 290.94 acres (117.74 hectares).

**N. Pine Snake No. 2006.15** (♂). (Lab Treatment) Current status = alive and healthy.

**2006 - 2007:** This snake was captured in trap 24 along the perimeter drift fence by EcolSciences, Inc. on 05/17/06. In 2006-07, this snake overwintered in HA's lab and was released into AH 4, a two winter treatment, on 04/03/07. No movement data was collected because the snake's radio-transmitter was non-functional for the season. In the 2007-08 winter, it hibernated in AH 4.

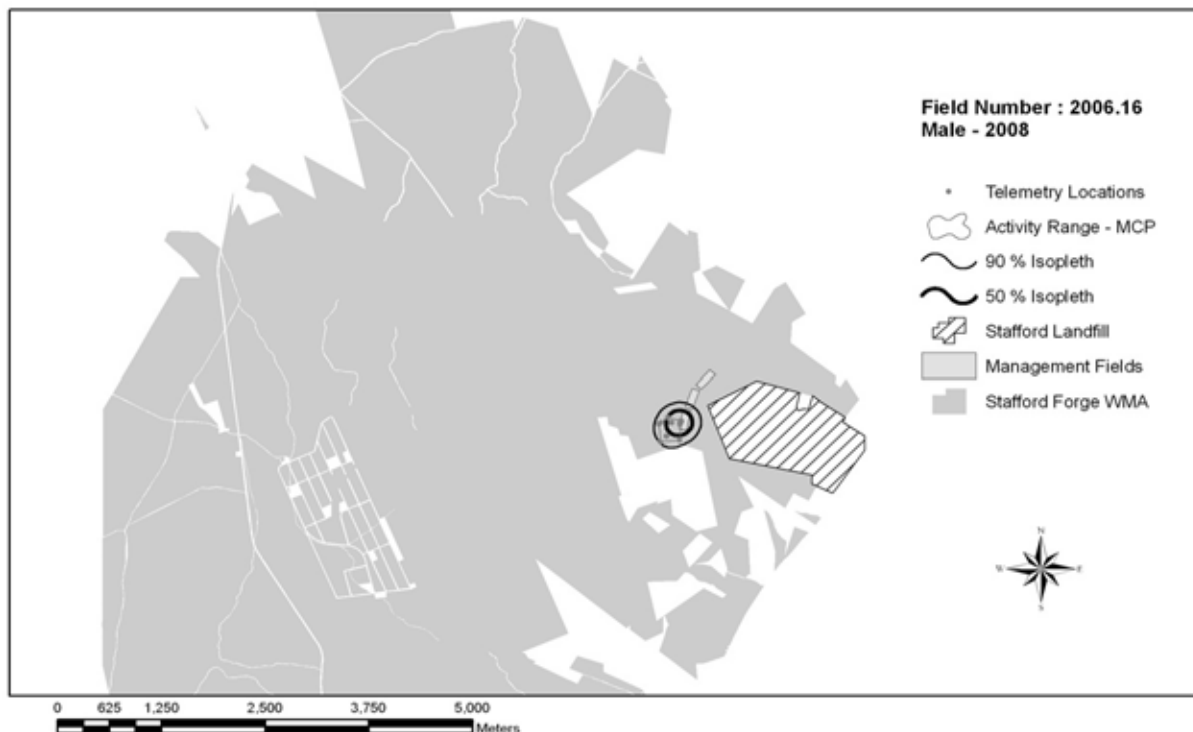


**2008:** On 06/11/08 this snake was recaptured within the AH 4 corral. The snake was collected for transmitter removal. Upon examination, the snake was determined to be of poor body weight, so it was kept in the lab and put on a feeding schedule in order to improve its overall health. By 10/03/08 the snake was healthy enough to be 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 1 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 animal 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 is currently overwintering in the mound in MF 2 as described above.

**N. Pine Snake No. 2006.16** (♂). (Lab Treatment) Current status = alive and healthy.

**2006 - 2007:** This snake was originally captured by EcolSciences, Inc. in trap number 27 along the perimeter drift fence on 05/18/06. This snake overwintered in the HA lab during the 2006-07 winter, due to poor health. It was released into AH 1, a two winter treatment, on 04/03/07. The snake was confined to the one acre corral for the entirety of the field season and overwintered there.

**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 animal 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 to overwinter. Pine snake No. 2006.19 is overwintering in AH 1 as well.

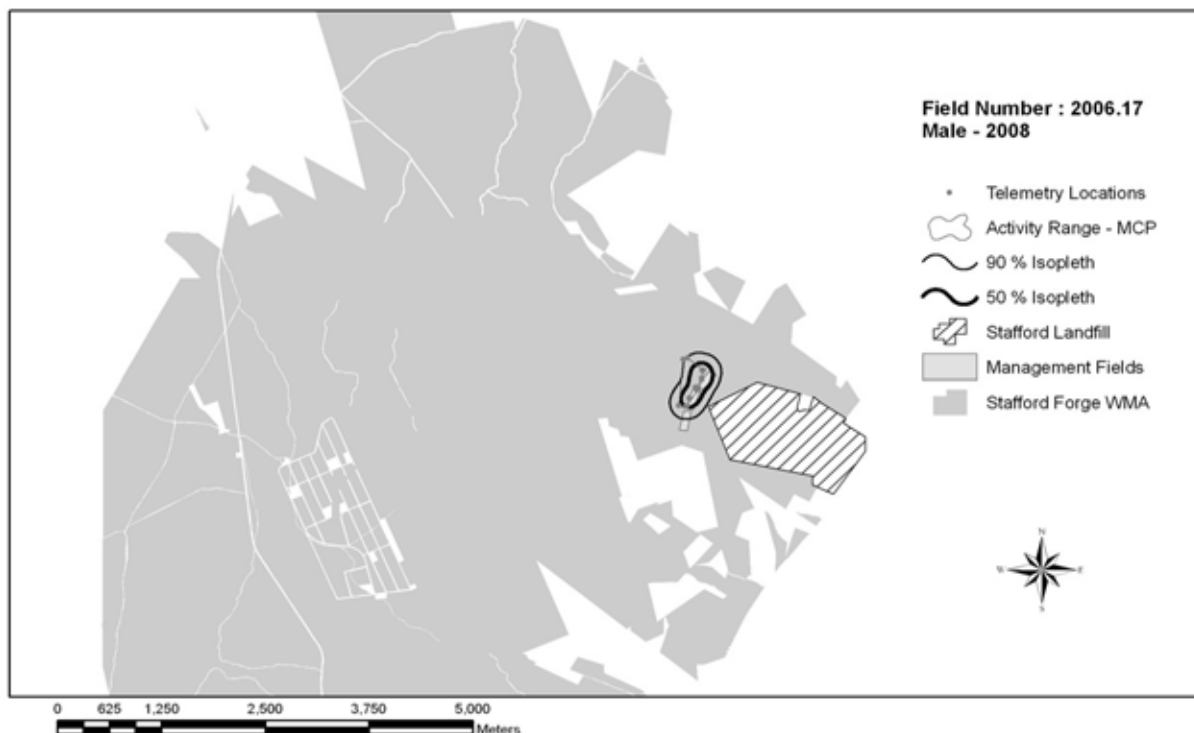


**Figure 11.** Radiotelemetry locations and activity range (minimum convex polygon and 50% and 90% isopleth from kernel analysis) for pine snake # 2006.16. The area used while being radio-tracked in 2008 is 16.77 acres (6.78 hectares).

**N. Pine Snake No. 2006.17** (♂). (Lab Treatment) Current status = alive and healthy.

**2006 - 2007:** This snake was captured by EcolSciences, Inc. on 05/21/06 in trap 18 along the perimeter drift fence. This snake overwintered in the HA lab due to poor health during the 2006-2007 winter. It was released into AH 6, a two-winter treatment, on 04/03/07. It was radio-tracked inside of the one acre AH 6 corral throughout the entire season. In the 2007-08 winter, the snake hibernated in AH 6.

**2008:** The snake egressed from AH 6 in April, 2008. The old transmitter was removed on 07/08/08 and the new one was implanted on 08/04/08. This animal was relocated 37 times in 2008. After surgery, the animal was released outside of the corral along the forest edge west of AH 6. This animal 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 is currently overwintering in NH B (30 meters west of MF 3). Pine snakes 2006.08 and 2007.03 are also overwintering in this location.

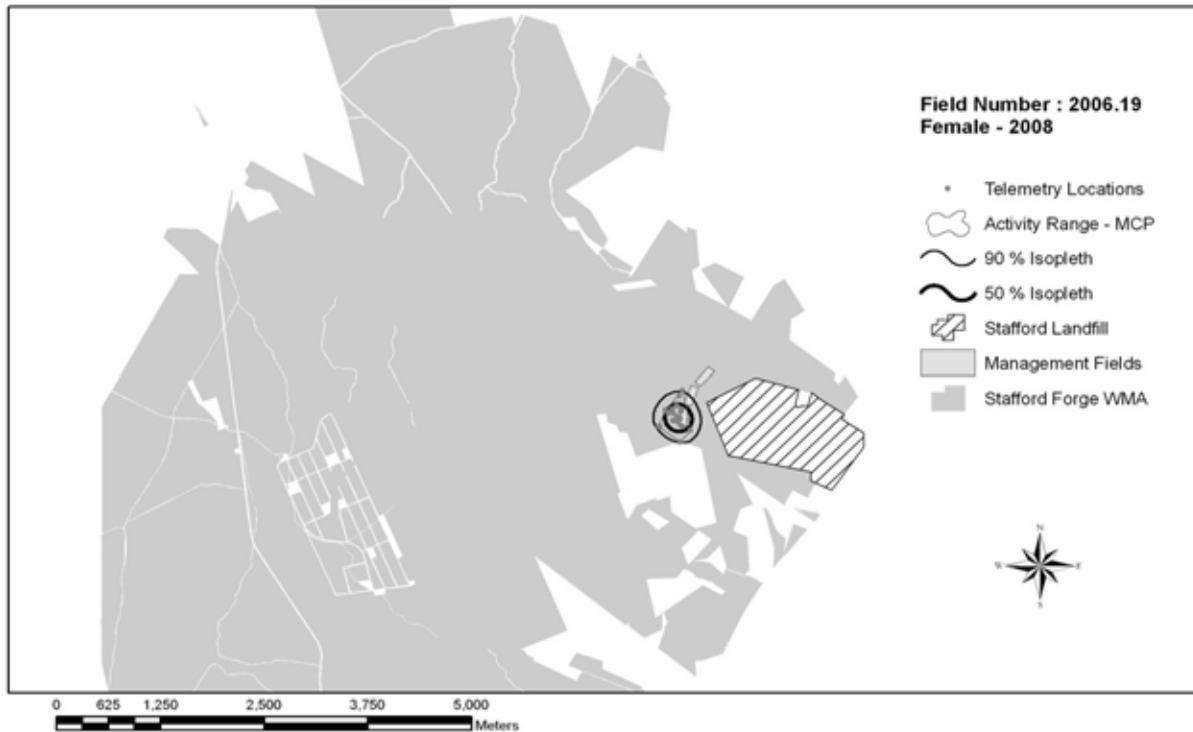


**Figure 12.** Radiotelemetry locations and activity range (minimum convex polygon and 50% and 90% isopleth from kernel analysis) for pine snake # 2006.17. The area used while being radio-tracked in 2008 is 27.9 acres (11.29 hectares).

**N. Pine Snake No. 2006.19** (♀). (Lab Treatment) Current status = alive and healthy.

**2006 - 2007:** This snake was originally captured by EcolSciences, Inc. on 05/24/06 in the NW corner of the (then existing) firearms shooting range. It laid eggs in the field which were subsequently predated. It overwintered in HA's lab in 2006-2007 winter season due to exaggerated breathing and a migrating transmitter. Its transmitter was removed on 09/06/06 for health reasons. It was released into AH 1 (two winter treatment) on 04/03/07 without a transmitter. It was observed by HA staff in AH 1 on 09/10/07 in good health. The snake spent the 2007-08 winter in AH 1.

**2008:** In late spring this animal was captured within the AH 1 corral. Due to good health conditions, HA implanted a transmitter in this snake on 07/17/08. It was relocated 45 times during the 2008 field season. After release, the animal used habitat south and west of the management fields. This snake used many man-made berms along the access road, the outer corral paths, and the management fields prior to returning to AH 1 where the animal is currently overwintering. Pine snake 2006.16 is hibernating in this location as well.



**Figure 13.** Radiotelemetry locations and activity range (minimum convex polygon and 50% and 90% isopleth from kernel analysis) for pine snake # 2006.19. The area used while being radio-tracked in 2008 is 33.87 acres (13.7 hectares).

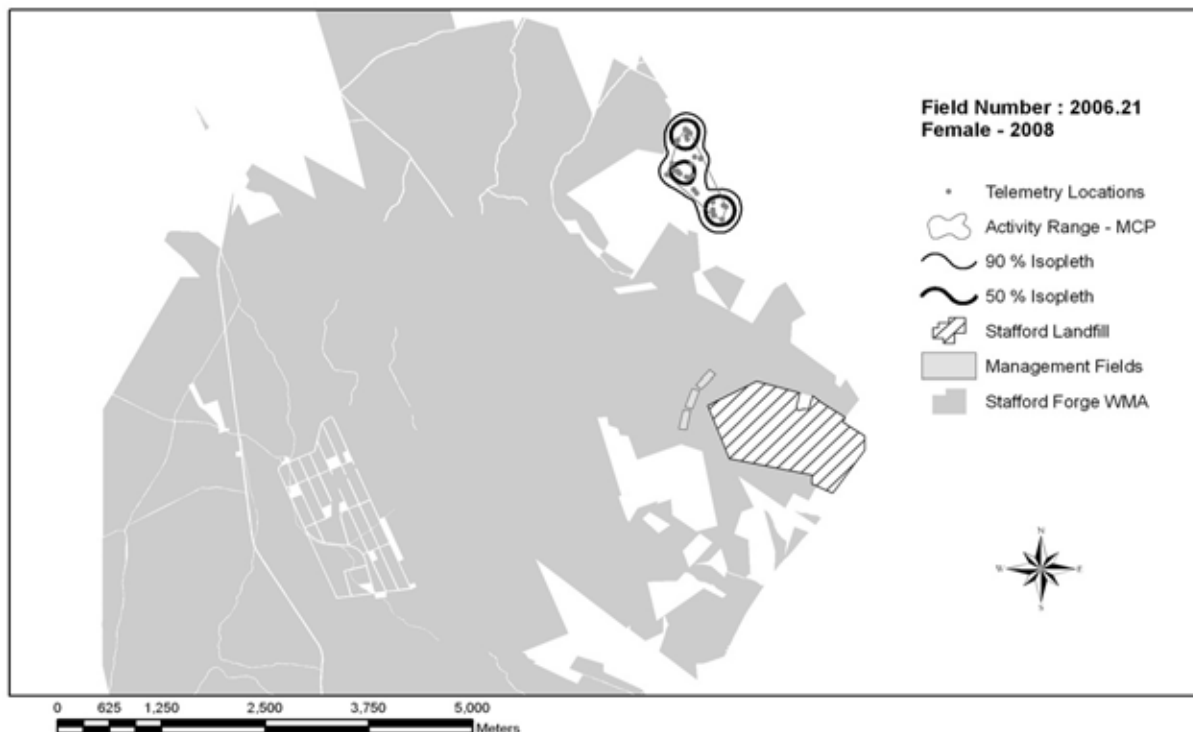
**N. Pine Snake No. 2006.20** (♂). (Treatment B/2 winter) Current status = deceased.

**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.

**N. Pine Snake No. 2006.21** (♀). (Treatment A/1 winter) Current status = alive and healthy.

**2006 - 2007:** This snake was originally captured in trap 95 along the perimeter drift fence by EcolSciences, Inc. on 05/27/06. This snake was released into AH 2, a one winter treatment, on 09/22/06 and hibernated there for the 2006-07 winter. This snake was tracked within the AH 2 enclosure until 05/03/07 when it was captured in a corral trap attempting to egress from the den. In the 2007-08 winter, this snake hibernated in a natural den (NH K) within an upland oak/pine forest on privately owned land approximately 2.4 kilometers north of the management fields.

**2008:** The snake egressed from NH K in April, 2008. This snake was relocated 49 times during the 2008 field season. In May, two different male pine snakes were captured within close proximity of this animal, suggesting that this female was ovulating. As with 2006.09, one male was observed coiled next to this female and another was observed possibly in the process of scent trailing her shortly after she was relocated on the move. Due to the upcoming transmitter failure date, the snake was collected for transmitter removal surgery on 05/19/08. The new, two-year transmitter was implanted on 07/29/08. This animal spent the remainder of the 2008 season in the same habitat as last year. 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. Ultimately, the snake selected a different overwintering location (NH R) 1.15 kilometers N/NW from where it hibernated last winter. The only noticeable entrance to this particular hibernaculum was a small hole in the forest floor.



**Figure 14.** Radiotelemetry locations and activity range (minimum convex polygon and 50% and 90% isopleth from kernel analysis) for pine snake # 2006.21. The area used while being radio-tracked in 2008 is 89.61 acres (36.26 hectares).

**N. Pine Snake No. 2006.22** (♂). (Treatment B/2 winter) Current status = deceased.

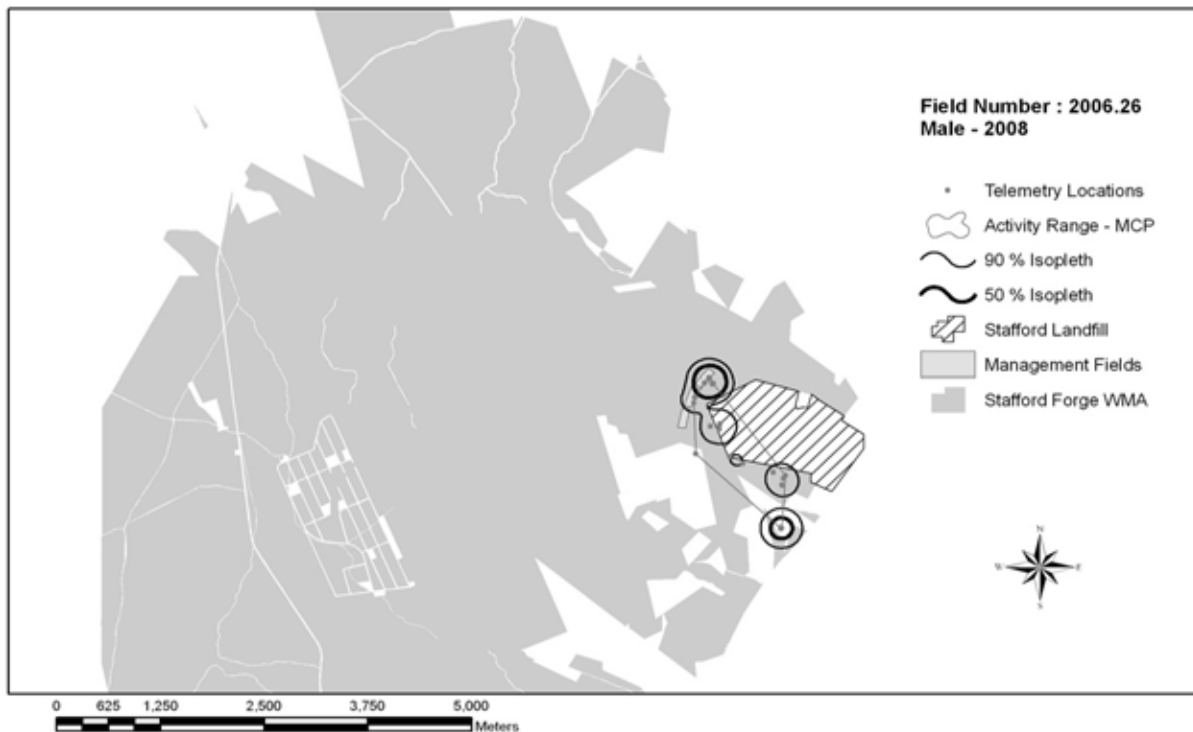
**2006 - 2007:** This snake was originally captured by EcolSciences, Inc. in trap 95 along the perimeter drift fence on 05/27/06. This snake was released into AH 1, a two winter treatment, on 09/22/06 where it spent the 2006-07 winter. On 04/24/07 this snake was found in the west trap of AH 1 attempting 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 where 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.

**N. Pine Snake No. 2006.26 (♂).** (Treatment A/1 winter) Current status = alive and healthy.

**2006 - 2007:** This snake was originally captured by EcolSciences, Inc. during the summer of 2006. It was released into AH 2, a one winter treatment, on 09/22/06 where it overwintered in 2006-07. In 2007, despite exclusion efforts, this snake was found in three (3) different locations within the Stafford Park property boundary. Habitat use in 2007 was comprised mainly of a narrow strip of forest between the southeast edge of MF 3 and the northwest property boundary of Stafford Park. The animal selected a natural den (NH A) within this area for hibernation in the 2007-08 winter with 2006.11. There was a moderately sized hole in the forest floor within a few meters of the snake's actual location. It is likely that this is the entrance to this den.

**2008:** In April, 2008 the snake egressed from NH A. This snake was relocated 63 times during the 2008 field season. It was collected for transmitter surgery on 05/13/08. The old transmitter was removed in June, 2008 and the new one was implanted on 07/17/08. The animal 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 animal was captured twice in the perimeter drift fence trap line. The animal ultimately utilized habitat south of the Stafford Park property and is currently overwintering in NH N, a natural den identified through radiotelemetry in 2007. Pine snake 2007.05 is overwintering at this location as well. A small hole in the forest floor was noted near this snake's hibernaculum.

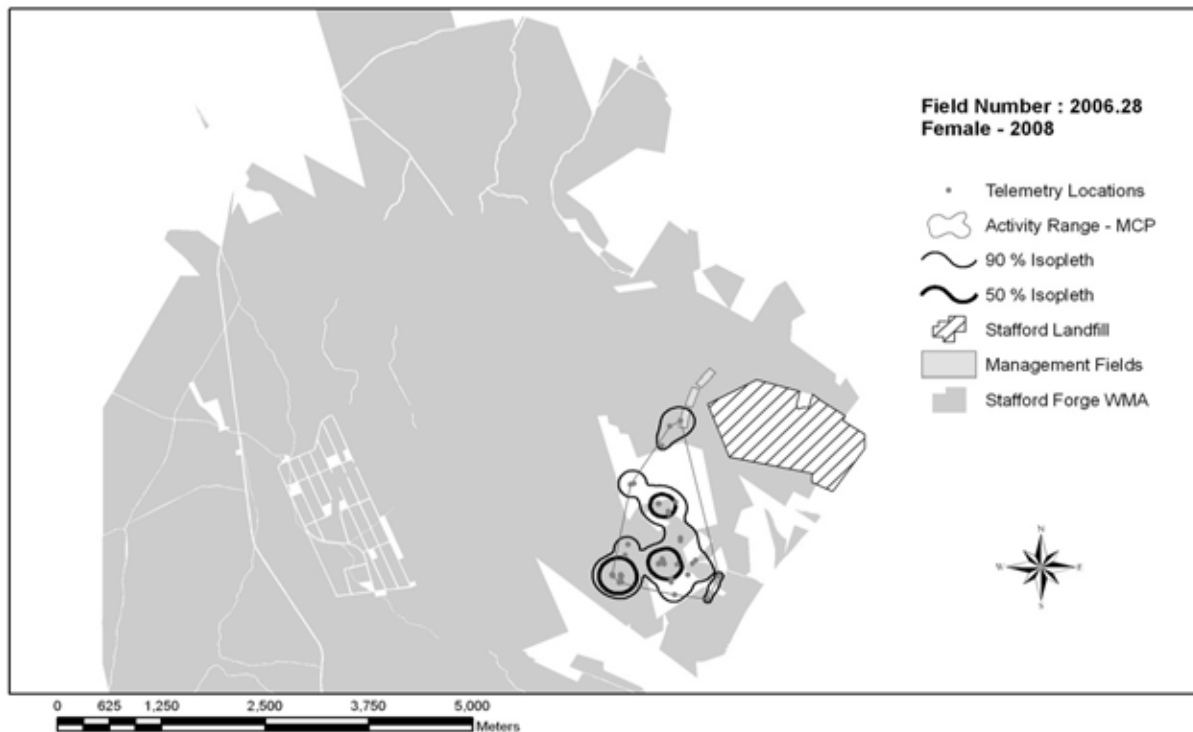


**Figure 15.** Radiotelemetry locations and activity range (minimum convex polygon and 50% and 90% isopleth from kernel analysis) for pine snake # 2006.26. The area used while being radio-tracked in 2008 is 242.76 acres (98.24 hectares).

**N. Pine Snake No. 2006.28 (♀).** (Lab Treatment) Current status = alive and healthy.

**2006 - 2007:** This snake was initially captured by HA on the landfill on 06/23/06. This snake was withheld in the HA lab for the 2006-07 winter and was released into AH 1, a two winter treatment, on 04/03/07. This snake was captured in the west corral trap on 04/20/07 attempting to egress into the three-acre outer corral. Prior to the fire on 05/16/07, this snake was consistently relocated underground in a small sandy berm along the outer corral path on the W/SW side of the outer corral. On 05/17/07, the day after the fire, this snake was observed leaving the berm and was relocated into AH 2 due to fire damage to AH 1. On 06/17/07 it was captured in an AH 2 corral trap and moved back into AH 1. For the remainder of the field season it was radio-tracked inside of the one acre AH 1 enclosure and hibernated there during the 2007-08 winter.

**2008:** This snake egressed from AH 1 on 05/09/08 and traveled into an oak/pine forest southwest of the management fields. This snake was removed from the field on 05/19/08 and a new, two-year transmitter was implanted on 07/11/08. This animal was relocated 55 times during the 2008 field season. This snake used different habitats south of the Stafford Park property, including several relocations within a forested wetland. On 10/05/08 it moved to a newly discovered natural den (NH S) where it is currently overwintering. No obvious entrance hole was detected near this snake's overwintering location.

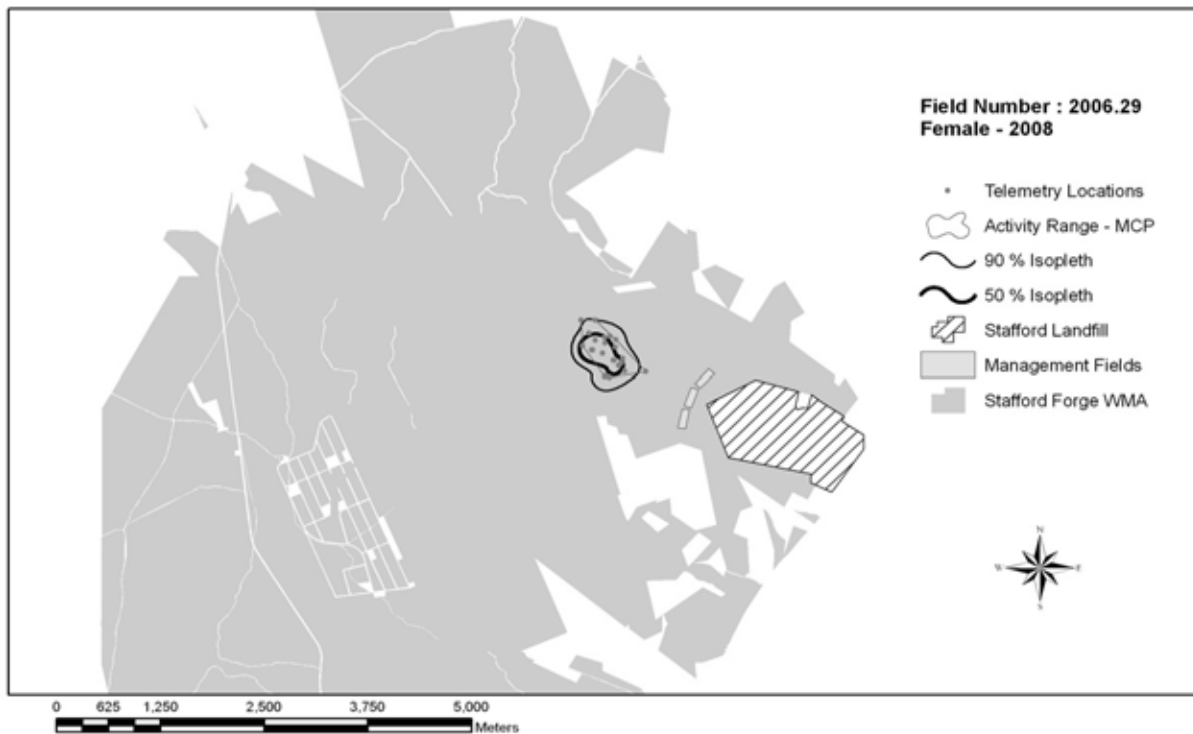


**Figure 16.** Radiotelemetry locations and activity range (minimum convex polygon and 50% and 90% isopleth from kernel analysis) for pine snake # 2006.28. The area used while being radio-tracked in 2008 is 444.61 acres (179.92 hectares).

**N. Pine Snake No. 2006.29** (♀). (Treatment B/2 winter) Current status = alive and healthy.

**2006 - 2007:** This snake was captured on 06/26/06 in trap 97 of the perimeter drift fence by EcolSciences, Inc. The snake was gravid and laid 10 eggs in the HA lab. It was released into AH 6, a two winter treatment, on 09/22/06 where it overwintered during 2006-07. On 04/24/07 it was captured in the west corral trap trying to leave the den and was released into the three-acre enclosure. On 05/17/07, the day after the fire, this snake was relocated in a mammal burrow behind the management fields. The snake had escaped the corral enclosure during the fire, despite the outer corral fence remaining intact. On 05/20/07, the snake was found on the surface and recaptured. The animal was released back into AH 6 where it was radio-tracked throughout the remainder of the season.

**2008:** The snake was collected from the AH 6 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 animal 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 animal is currently overwintering in a section of upland pine forest in a new natural den (NH T).



**Figure 17.** Radiotelemetry locations and activity range (minimum convex polygon and 50% and 90% isopleth from kernel analysis) for pine snake # 2006.29. The area used while being radio-tracked in 2008 is 71.44 acres (28.91 hectares).

**N. Pine Snake No. 2006.30** (♀). (Lab Treatment) Current status = unknown.

**2006 - 2007:** This snake was captured by HA staff on 06/28/06. The snake was gravid and laid 9 eggs in HA's lab on 07/07/06. It overwintered in the HA lab for the 2006-2007 winter and was released into Den 4, a two winter treatment, on 04/03/07. HA staff experienced problems with this snake's transmitter up until 06/01/07 when the transmitter failed completely. The animal was confined within the AH 4 enclosure for the 2007-08 winter.

**2008:** Despite random searching efforts conducted at peak activity times and optimal climatic conditions, this snake was not observed within the AH 4 enclosure in 2008. All corral walls were lifted this season, so if alive, it has made an unobserved move away from the management fields.

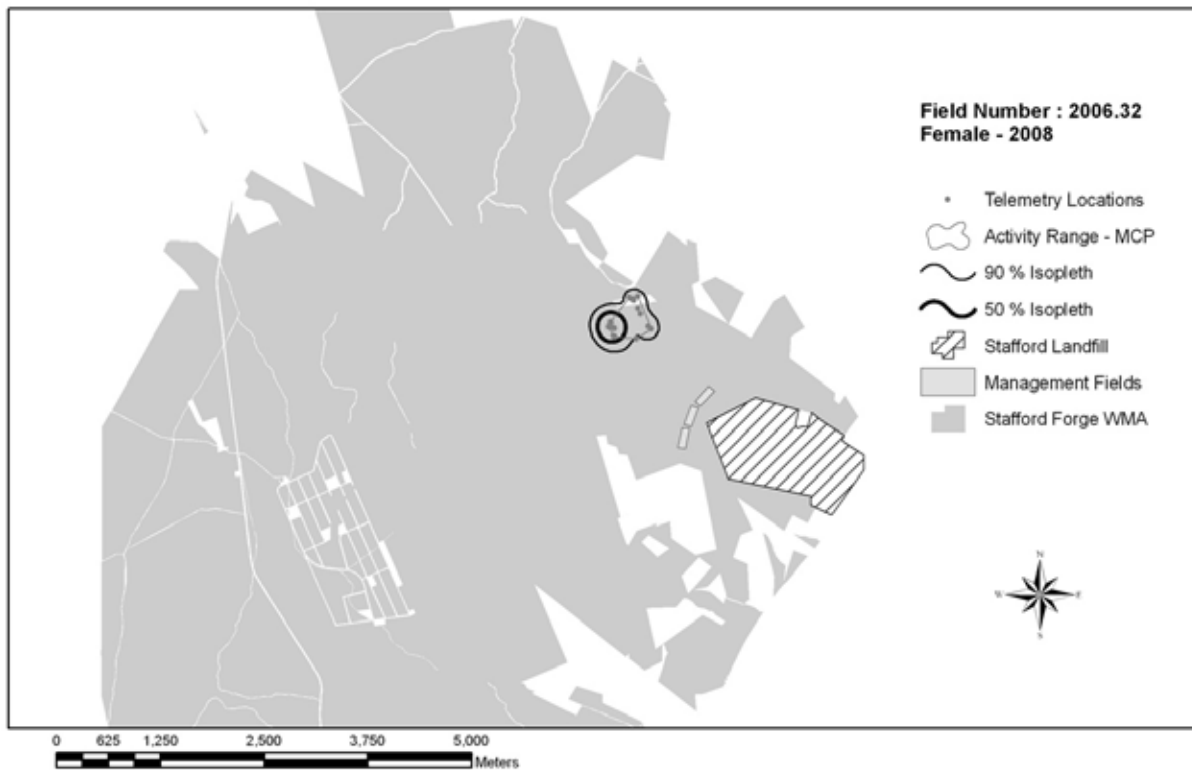
**N. Pine Snake No. 2006.32** (♀). (Treatment A/1 winter) Current status = alive and healthy.

**2006 - 2007:** This snake was originally captured in trap 61 along the perimeter drift fence on 07/08/06. It was implanted with a transmitter and released into AH 3, a one winter treatment, on 09/22/06, where the snake hibernated in the 2006-07 winter. Although the one winter treatments were opened in mid-April, this snake did not leave AH 3 until 07/05/07. During that time the animal was radio-tracked inside the hibernaculum. When this snake was relocated on 07/07/07 it was in heavily burned upland pine forest over 1.5 kilometers west of the management fields in the interior of SFWMA. Four days later this snake made another large move of over 1.5 kilometers to the north and was relocated within a few meters of Hay Road.

During the remainder of the season this snake was relocated in this same general area. It was relocated in both burned and unburned portions of the forest on the north and south sides of Hay Road. This snake hibernated in the winter of 2007-08 in a stump hole (NH D) in a lowland oak/pine forest, approximately 1.8 kilometers N/NW of the management fields and 30 meters from the edge of Hay Road in Stafford Forge Wildlife Management Area.

**2008:** The snake egressed from NH D on 05/03/08 and was observed to have extensive hibernation sores on its head and neck. It was collected for transmitter surgery on 05/13/08. The old transmitter was removed on 05/25/08 and the new one was implanted on 08/04/08. On 08/12/08, the snake was released and radio tracked for the remainder of the field season. It was relocated 49 times in 2008, mainly within the same home range it established in 2007. When the active season ended in mid-November 2008, this snake was underground in a stump hole in the same general vicinity where it overwintered the previous year. However, during a mid-winter check on the snake's location in January of 2009, it was found to have made a move of approximately 200 meters E/SE. 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, however there was a large amount of leaf litter on the forest floor at the snake's new location. This denning location has been designated NH W.





**Figure 18.** Radiotelemetry locations and activity range (minimum convex polygon and 50% and 90% isopleth from kernel analysis) for pine snake # 2006.32. The area used while being radio-tracked in 2008 is 41.64 acres (16.85 hectares).

***N. Pine Snake No. 2006.33*** (♀). (Treatment A/1 winter) Current status = deceased.

**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.

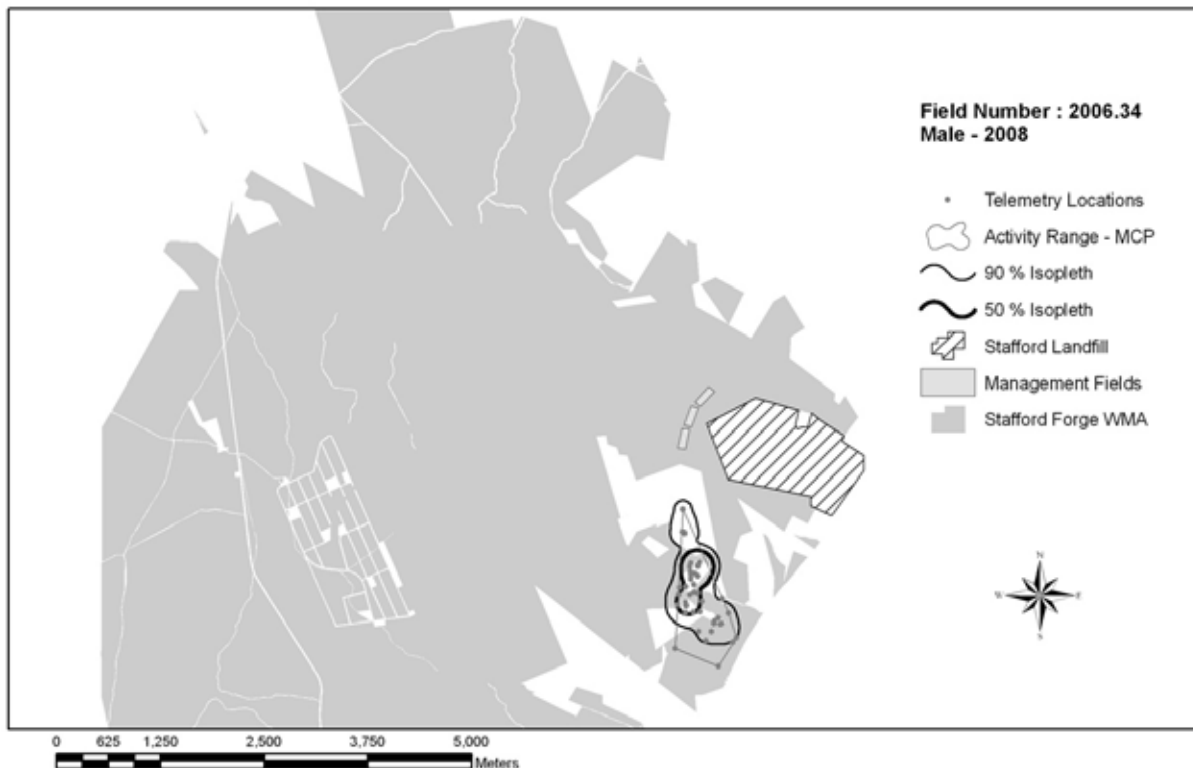
**2008:** This snake was observed on the surface near the entrance hole of NH E in March 2008 when HA staff were preparing to corral the denning site. The ambient air temperature was at or near 0 degrees Celsius at the time. HA decided that this animal was behaving in a manner that would result in its 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 by HA for further analysis.

**N. Pine Snake No. 2006.34** (♂). (Treatment A/1 winter) Current status = alive and healthy.

**2006 - 2007:** This snake was originally caught in trap 85 of the perimeter drift fence by EcolSciences, Inc. on 08/31/06. This snake overwintered in AH 2, a one winter treatment in 2006-07. This snake was caught in a corral trap attempting to egress from the den on 05/01/07. The snake was implanted with a transmitter on 05/02/07 and released the following day. The animal spent the remainder of the field season in habitat south of the Stafford Park property. During the 2007-08 winter, this snake hibernated in an upland oak/pine forest approximately 1.3 kilometers S/SW of the redevelopment site in a natural den (NH O).

**2008:** The snake egressed from NH O on 04/17/08. This snake was relocated 92 times in 2008. 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 animal was relocated 50 cm from a hole where an ovulating female, pine snake 2007.05, was located.

No breeding attempts were observed, but it is likely that this behavior occurred. This animal continued to utilize the aforementioned forested wetland and the adjacent oak/pine forest for the remainder of the 2008 field season. This snake spent the majority of August in a stump hole located within the previously mentioned forested wetland. Throughout 2008, this snake was relocated within the same home range identified via radiotelemetry in 2007. It is currently overwintering in a natural den (NH V) 3 meters from one of its relocation points from 2007. There is a small nondescript hole within one to two meters of the snake's current denning location.



**Figure 19.** Radiotelemetry locations and activity range (minimum convex polygon and 50% and 90% isopleth from kernel analysis) for pine snake # 2006.34. The area used while being radio-tracked in 2008 is 185.37 acres (75.02 hectares).

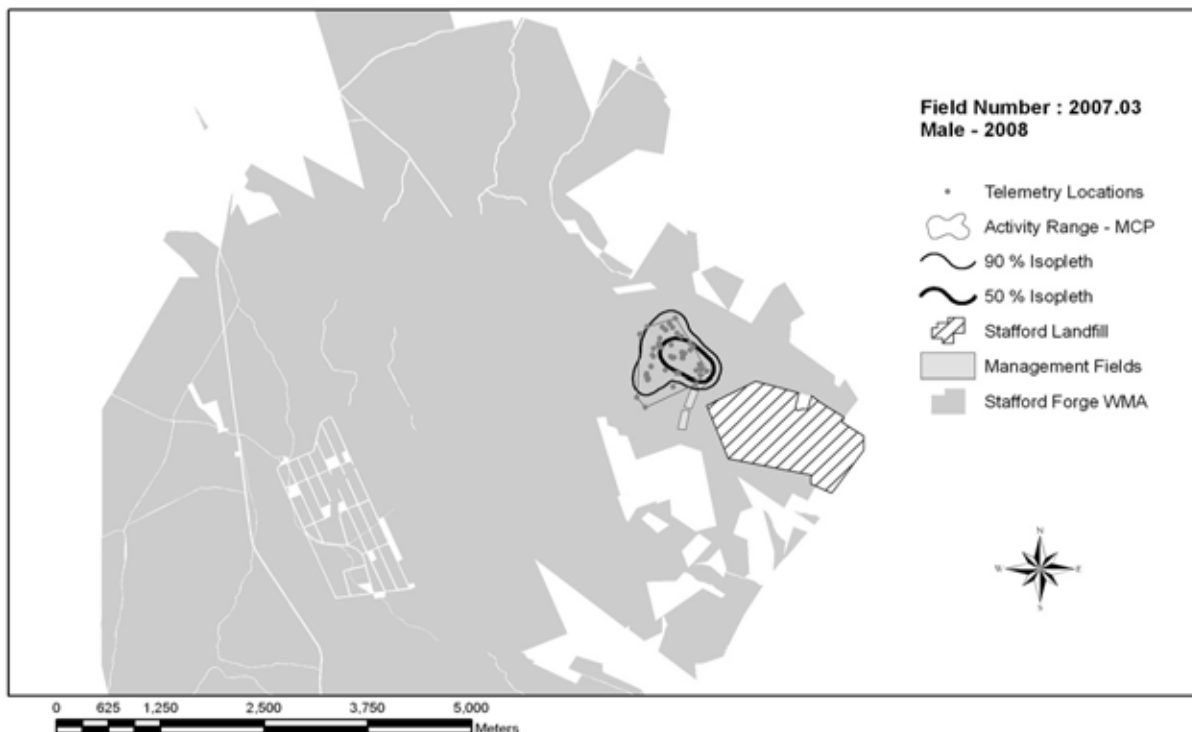
## NON-SHIFTED SNAKES

*N. Pine Snake No. 2007.03* (♂). Current status = alive, but has poor body weight.

**2007:** 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 fields. This animal was captured during a random search effort on 05/24/07 by HA staff. This snake was implanted with a transmitter and released on 05/31/07. Throughout the field season, this snake never traveled far from its original capture location. It was often relocated in the burned pine forest W/NW of the management fields. This snake also utilized the man-made earth berm along MF 3. This snake hibernated in a large mammal burrow (NH B) in the upland pine forest 30 meters NW of AH 6 for the 2007-08 winter.

**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. This animal proceeded to travel W/NW into the same habitat it used in 2007. It was in an opaque state 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 the cedar swamp wetland 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 Rd. pond. Throughout the entire 2008 active field season this particular snake was noted to be of poor body weight. Very little evidence of feeding behavior was observed during the entire season and the snake was never positively identified as having recently fed. Over the past two seasons this snake has been the very last one to enter a permanent overwintering station.

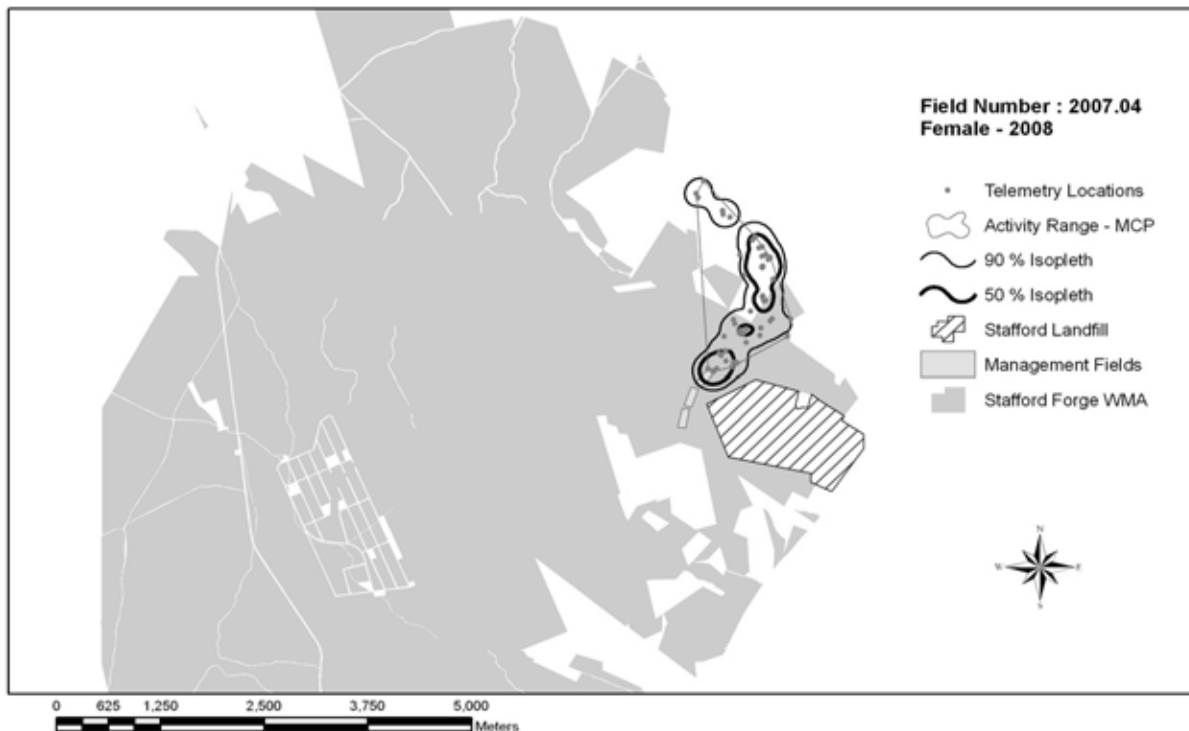


**Figure 20.** Radiotelemetry locations and activity range (minimum convex polygon and 50% and 90% isopleth from kernel analysis) for pine snake # 2007.03. The area used while being radio-tracked in 2008 is 152.87 acres (61.87 hectares).

When the active 2008 radio-tracking season ended in mid-November, this snake was underground in a stump hole immediately adjacent to a small trail approximately 300 meters NW of AH 6. However, when HA staff checked on the snake's location in January of 2009 it was found to have reentered the mammal burrow it had utilized as an overwintering site during the previous year. Pine snakes 2006.08 and 2006.17 are at the same location. The 2008 relocations of this snake are within the same home range identified via radiotelemetry in 2007.

**N. Pine Snake No. 2007.04 (♀).** Current status = alive and healthy.

**2007:** This snake was originally captured by HA staff on 05/25/07 in an island of disturbed pine/oak forest on the east side of the Stafford Park construction site. It was gravid and held in AH 1 until egg deposition. The snake was implanted with a transmitter on 07/13/07 and released the following day. This snake immediately moved N/NW from the construction site and crossed the Mill Creek wetland corridor into an upland oak/pine forest on privately owned land. Many relocations occurred in an upland oak/pine forest situated between Mill Creek and Route 72, often times on privately owned property. This snake hibernated in 2007-08 in a mammal burrow (NH L) at the base of a thicket of mountain laurel only 15 meters from Route 72 on privately owned land.



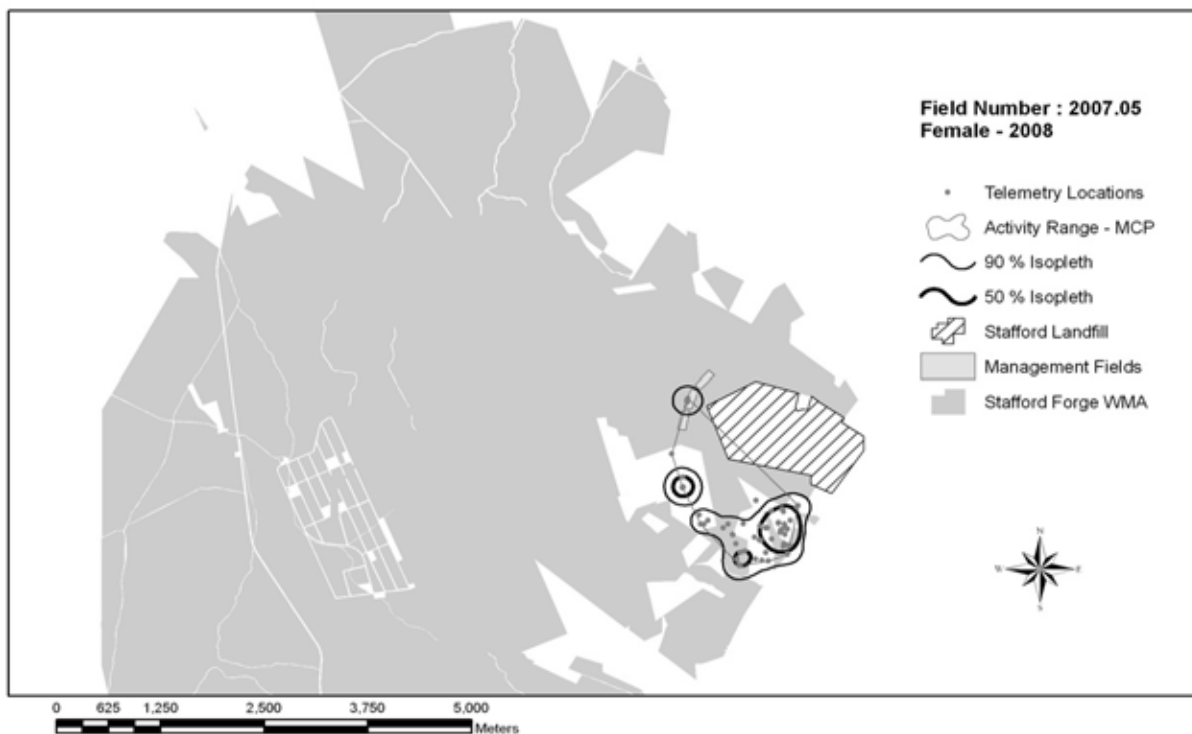
**Figure 21.** Radiotelemetry locations and activity range (minimum convex polygon and 50% and 90% isopleth from kernel analysis) for pine snake # 2007.04. The area used while being radio-tracked in 2008 is 415.00 acres (167.94 hectares).

**2008:** On 04/17/08 this snake was located 100 meters from NH L, indicating that it had egressed prior to this date. This snake was relocated 86 times in 2008. On 06/26/08 it was observed actively raiding an eastern cottontail rabbit nest. HA staff observed the snake kill and eat five young rabbits from within the nest. The animal spent the next few weeks concealed within a forested wetland before making a large move towards MF 3 on 07/21/08. On 07/23/08 this snake was observed killing and eating a juvenile rabbit. From 07/25/08 to 08/05/08 the snake was concealed within the perimeter berm along the northern edge of MF 3.

On 08/13/08 it was relocated, yet again, within the perimeter berm of MF 3. Over the course of the next month this snake would repeatedly use 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. There was a small hole at the base of a mountain laurel bush near the snake's location. This portion of forest was only lightly burned during the 2007 forest fire. 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 in pine/oak forest. This new denning location has been designated NH U.

*N Pine Snake 2007.05* (♀). Current status = alive and healthy.

**2007:** 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. It was gravid and released into AH 4 until egg deposition. It was implanted with a transmitter on 07/17/07 and released. Almost all relocations occurred in an oak/pine or pine/oak forest within a privately owned parcel of land surrounded by Stafford Forge WMA south of the construction site. In 2007-08 this snake hibernated in a portion of oak/pine forest south of the Stafford Park Business Site (NH N). There was a moderately sized hole in the ground within a few meters of the snake's location. This was presumed to be the entrance to the den.



**Figure 22.** Radiotelemetry locations and activity range (minimum convex polygon and 50% and 90% isopleth from kernel analysis) for pine snake # 2007.05. The area used while being radio-tracked in 2008 is 426.81 acres (172.72 hectares).

**2008:** This snake was relocated 95 times in 2008. On 04/17/08 this snake was located in a stump hole that it had previously used in 2007. This is not where the animal was last relocated when checked upon during the 2007-08 winter. This implies that the animal egressed from NH N prior to this date. This female ovulated and was observed breeding with a small male pine snake on 05/21/08.

The same small male pine snake was observed within close proximity to her on 05/23/08 at a location approximately 200 meters from where the breeding observation occurred on 05/21/08. Another male pine snake, 2006.34, was observed within 50 cm of this female on 06/10/08, implying further breeding attempts. For the majority of the 2008 field season, this animal traveled within the home range identified via radiotelemetry in 2007. However, on 06/18/08 this snake made a significant movement north and was relocated inside AH 3 on management field 2. Over the next 5 relocations, it was observed excavating and occupying a nest burrow in the earthen berm that borders the western edge of management field 2. Post egg deposition (posterior skin folds observed), the snake made a large move S/SE, back into the habitat she had been previously using prior to nesting. On 09/29/08 this snake was found underground at a location previously used on 09/28/07, suggesting a possible seasonal habitat preference. The snake is currently overwintering in NH N again. Pine snake 2006.26 is overwintering in this location as well.

**N. Pine Snake No. 2007.06** (♀). Current status = deceased.

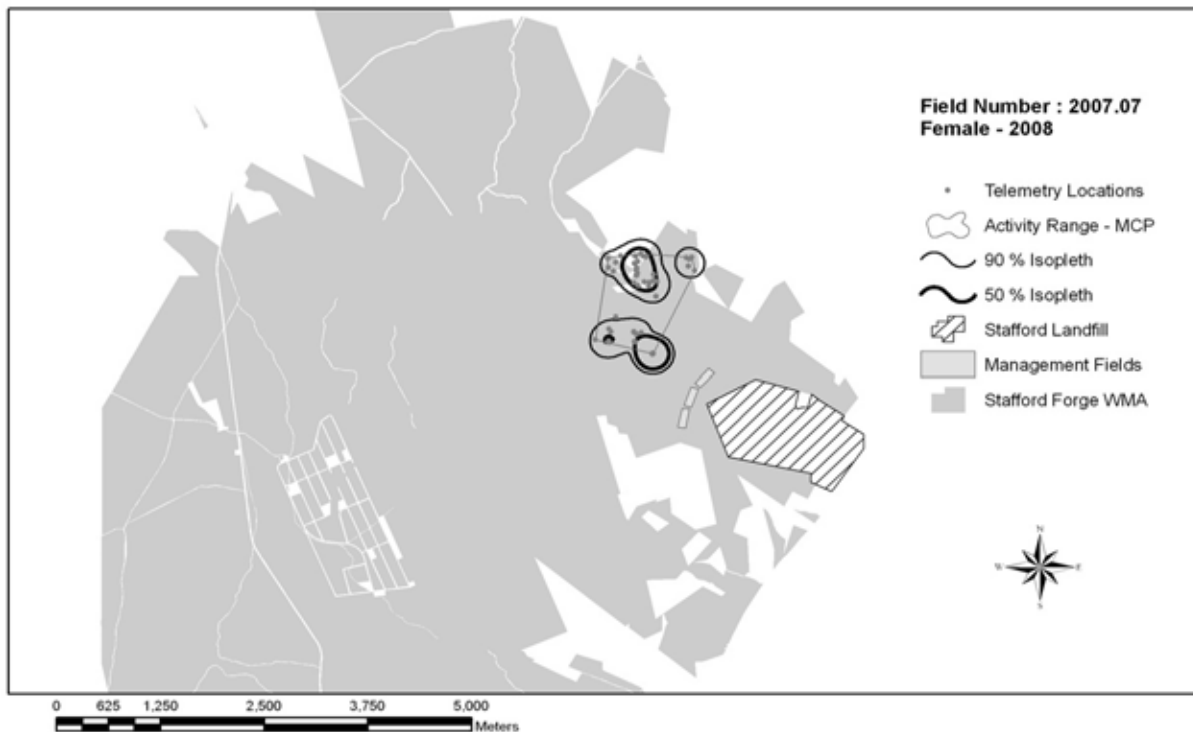
**2007:** This snake was originally captured by HA staff while radio-tracking. This snake was found traveling in burned upland pine forest 15 meters from pine snake 2006.21's location on 06/03/07. Due to the small size of this snake, it was decided that a smaller, one year transmitter would be needed 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.

**N. Pine Snake No. 2007.07** (♀). Current status = alive and healthy.

**2007:** This snake was originally captured on 06/03/07 by HA staff as it was crossing Hay Road. The snake was gravid and held in AH 6 until egg deposition. It was implanted with a transmitter on 07/17/07 and released the following day. This snake never traveled far from where it was captured. This snake used a variety of habitats throughout the field season, including unburned and heavily burned forest, wetland edges, and cedar swamps. It hibernated within Stafford Forge Wildlife Management Area in an abandoned mammal burrow (NH C) in a heavily burned section of pine forest.



**Figure 23.** Radiotelemetry locations and activity range (minimum convex polygon and 50% and 90% isopleth from kernel analysis) for pine snake # 2007.07. The area used while being radio-tracked in 2008 is 267.67 acres (108.32 hectares).

**2008:** On 05/10/08 this snake egressed from NH C and was relocated 87 times in 2008. Immediately after emerging, 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 forested wetland habitat on the northeast side of Mill Creek. Six days later, this snake again made a large move back to the upland pine forest it had previously favored. On 06/24/08, it again moved E/NE across the Mill Creek wetland corridor into privately owned upland oak/pine habitat. This particular section of forest was never used by this animal during the 2007 active field season. However, during both the 2007 and 2008 field seasons another study snake (Pine snake 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 NH C and remained there for the remainder of the active season. Pine snake 2008.02 is also overwintering at this location.

**N. Pine Snake No. 2007.09 (♂).** Current status = alive and healthy.

**2007:** This snake was originally captured by HA staff on 06/04/07, when it was found concealed within a trash pile. The location was adjacent to an ATV trail NE of Grays/Micaja Road in heavily burned upland pine forest. The snake was implanted on 07/19/07 and released the following day. The majority of this snake's relocation points were over 4 kilometers NW of the Stafford Park property. This animal hibernated in a natural den (NH F) in burned upland pine forest in the NW section of Stafford Forge Wildlife Management Area.



**Figure 24.** Radiotelemetry locations and activity range (minimum convex polygon and 50% and 90% isopleth from kernel analysis) for pine snake # 2007.09. The area used while being radio-tracked in 2008 is 1041.6 acres (421.52 hectares).

**2008:** This snake was relocated 75 times in 2008 and had the largest home range of any pine snake tracked during the 2008 field season. At the start of the active field season, this snake was observed basking near the entrance to its winter den, but never left its immediate vicinity. After egression occurred, the snake traveled approximately 500 meters to the NW and concealed itself within a discarded truck tire for several days. It spent the majority of the field season in the large tract of upland pine forest along the western side of Grays/Micaja Road. It utilized both heavily and moderately burned portions of the forest and would frequently be found in and around red squirrel burrows/feeding stations. Between 09/19 and 09/24/08 this snake made an extremely large move of over 2 km to the NE, where it began to utilize a tract of privately owned property just south of Brighton Homes residential development.

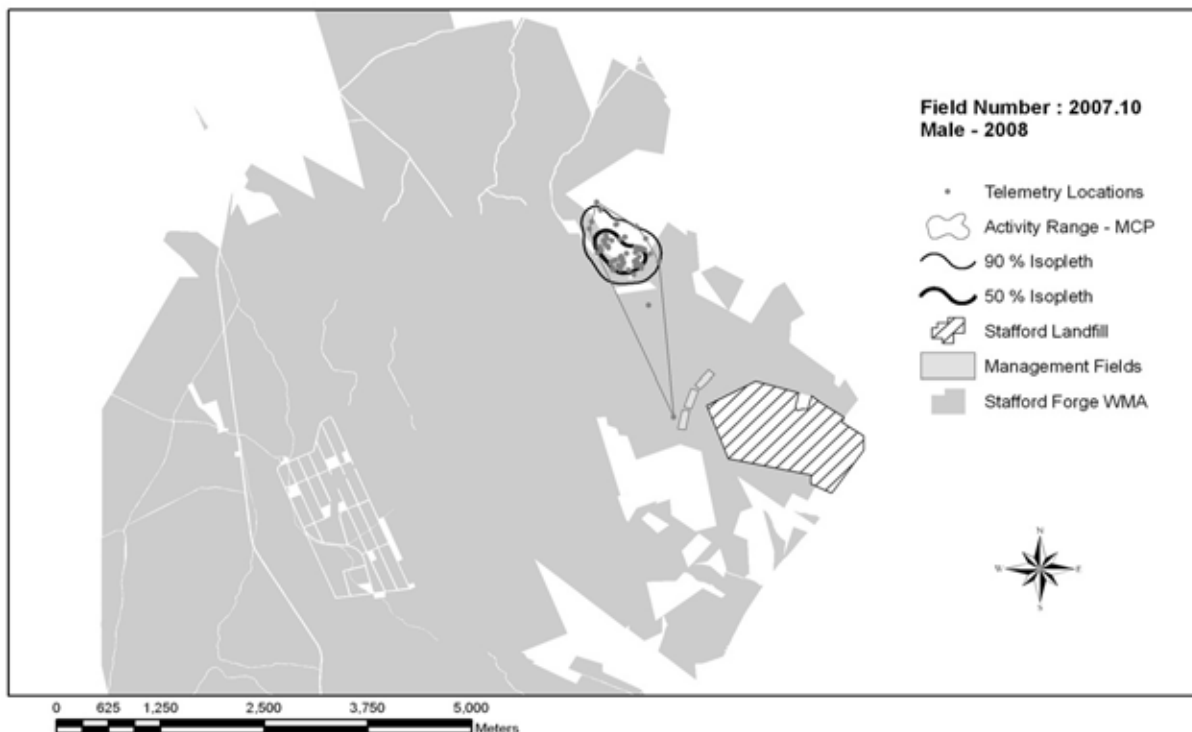
On 12/03/08, HA staff located this snake within an abandoned mammal burrow it had been previously tracked to on 10/13/08. The snake had been frequenting an area near a small stump hole approximately 0.37 miles north of this location from 10/15/08 - 10/25/08 when HA stopped radio-tracking this animal due to recently posted 'No Trespassing' signs. The animal is currently hibernating in the aforementioned abandoned mammal burrow (NH Y).



**N. Pine Snake No. 2007.10** (♂). Current status = alive and healthy.

**2007:** This snake was originally captured by HA staff on 06/05/07 traveling near the radio tower along the northern portion of SPR construction site. This snake was implanted with a transmitter on 06/26/07 and then released behind the management fields, due to the fact that the habitat the animal was captured in was not suitable because of ongoing construction. The animal stayed near the management fields until mid-July. On one relocation this snake was observed inside a squirrel's nest approximately 9 meters up at the top of a pitch pine tree. On 07/22/07 this animal was found 1.6 kilometers north of its previous relocation. It had crossed the Mill Creek wetland corridor into an upland oak/pine forest where it stayed for the remainder of the field season. The animal hibernated in a natural den (NH J) in this upland oak/pine forest within the boundary of Stafford Forge WMA. The only noticeable entrance underground was a small hole within a few meters of the snake's actual location.

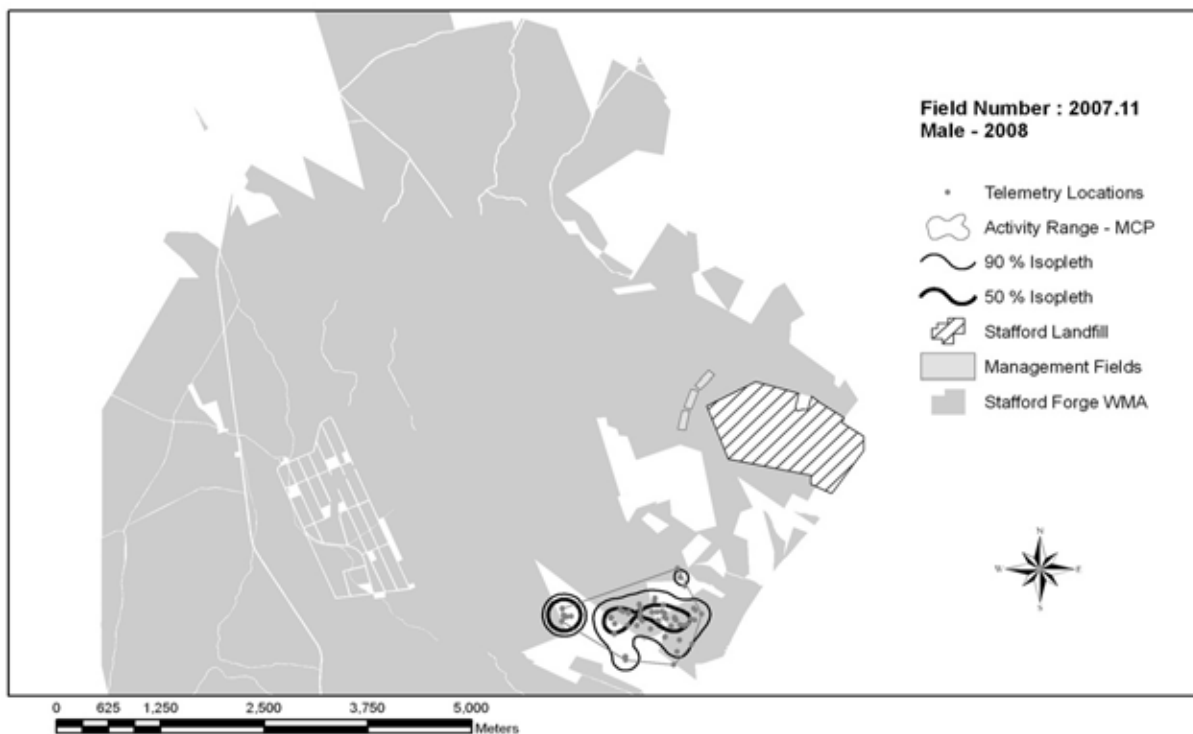
**2008:** This snake egressed from NH J prior to the first day of radiotelemetry on 04/17/08. It was relocated 84 times in 2008. In mid-May, the animal made a large movement back to the upland pine forest immediately west of AH 1 and was concealed in a debris pile along the AH 1 outer corral path. It then returned to habitat north of the Mill Creek wetland corridor. Other than this one particular move, this snake used the same general oak/pine forest habitat where it was relocated to the majority of the 2007 field season. On 10/15/08 this snake was relocated in a small nondescript hole at the base of a large scrub oak, and spent the remainder of the active field season there. This newly discovered natural den has been named NH Z.



**Figure 25.** Radiotelemetry locations and activity range (minimum convex polygon and 50% and 90% isopleth from kernel analysis) for pine snake # 2007.10. The area used while being radio-tracked in 2008 is 262.56 acres (106.25 hectares).

**N. Pine Snake No. 2007.11** (♂). Current status = alive and healthy.

**2007:** This snake was captured by HA staff on 06/15/07 while radio-tracking Pine Snake 2006.34. The capture location was near an old disturbed site in the forest approximately 1.5 kilometers south of the SPR property. The area is characterized by large grass covered piles of earth, old bottles, and broken glass. After its release, the snake spent the remainder of the field season south and southeast of the construction site. It was relocated in upland pine forest, oak/pine forest, and along the edge of a wetland corridor. A few relocations occurred within 50 meters of the southbound lane of the Garden State Parkway. This snake hibernated near Pine Snake 2007.14 in a disturbed pitch pine forest approximately 3 kilometers SE of the site in a natural den (NH H). In mid-March of 2008 it was found that this snake had moved out of NH H. It was tracked to a previously unknown hibernaculum approximately 1.3 kilometers to the SE. This move was noted after the area in which the snake had been overwintering had been recently set on fire via controlled burn. Whether or not this prompted the late season move is not known.

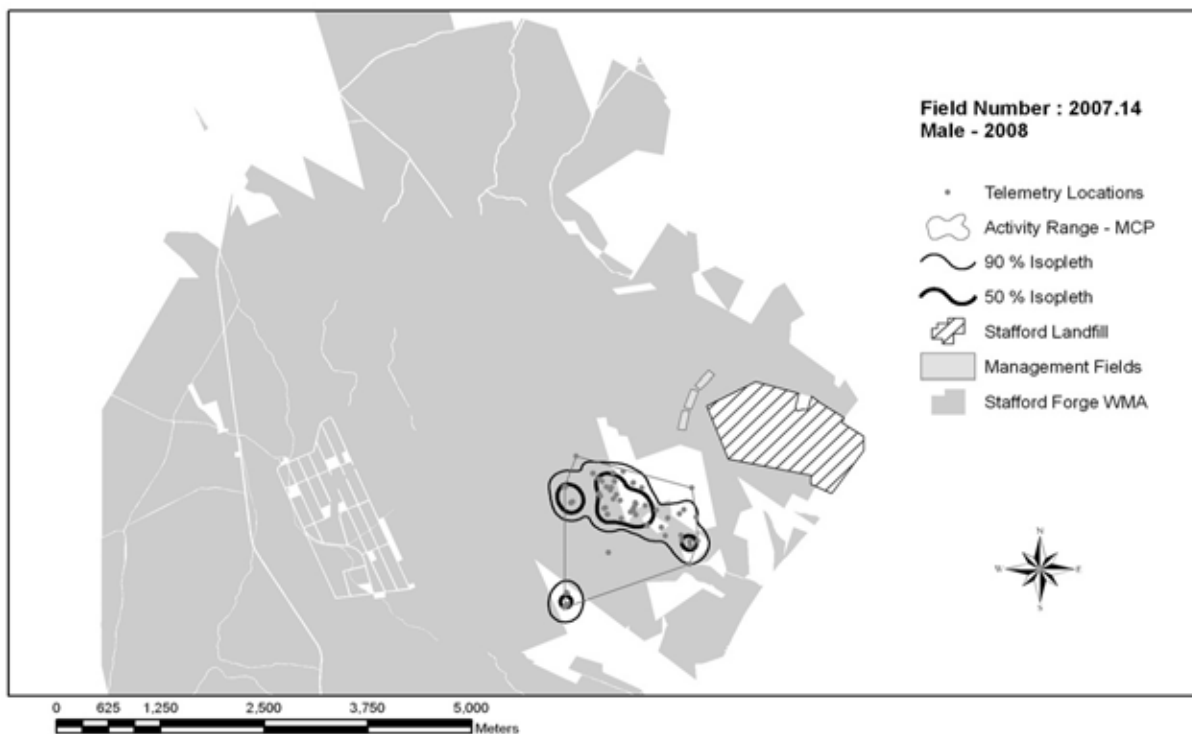


**Figure 26.** Radiotelemetry locations and activity range (minimum convex polygon and 50% and 90% isopleth from kernel analysis) for pine snake # 2007.11. The area used while being radio-tracked in 2008 is 317.62 acres (128.53 hectares).

**2008:** This animal had already egressed from its late season denning site by 04/17/08 when the active 2008 radio-tracking season started. This snake was relocated 93 times during the 2008 field season. In May, it was observed using a variety of habitats within the same home range identified via radiotelemetry in 2007. This includes a location on 05/08/08 when both this animal and Pine Snake No. 2006.34 (both males) were found within a few meters of each other. On 05/23/08, HA staff observed this animal as having recently fed, evidenced by a pronounced bulge at mid-body. The snake was again observed in this condition on 06/20/08, indicating yet another successful feeding. On 08/27/08, the animal returned to its 2007-08 overwintering location (NH H). Here, HA staff located a nest of pine snake eggs and hatchlings (see Hatchling and Juvenile Snake Section). The snake remained in the general vicinity of NH H, sheltering in the various man-made berms prevalent at this old disturbed site until returning to NH H where the animal is now overwintering.

**N. Pine Snake 2007.14 (♂).** Current status = alive and healthy.

**2007:** This snake was originally captured on 08/11/07 near the large glass pile/dump south of the construction site. This was the same glass pile/dump where male Pine Snake 2006.34 was relocated nearby on several locations during the 2007 and 2008 field seasons and where Pine Snake 2007.11 was captured. It was implanted with a transmitter on 08/15/07 and released. This animal was often relocated inside or along the edge of a large wetland corridor that runs NE/SW approximately 1.6 kilometers S/SW of the construction site. This snake was also relocated several times at the glass pile/dump where it was originally captured, as well as in the surrounding oak/pine forest. This snake, along with Pine Snake 2006.34, used a shingle pile adjacent to the glass dump as a shedding station. On 11/03/07, this snake made a large move of approximately 1.6 kilometers to the SW. It hibernated near Pine Snake 2007.11 in an old disturbed pine forest approximately 3 kilometers SE of the SPR site in a natural den (NH G).



**Figure 27.** Radiotelemetry locations and activity range (minimum convex polygon and 50% and 90% isopleth from kernel analysis) for pine snake # 2007.14. The area used while being radio-tracked in 2008 is 556.65 acres (225.26 hectares).

**2008:** This snake was relocated 63 times in 2008. It emerged from NH G on 04/25/08 and immediately traveled northeast towards the habitat used in 2007. On a number of relocations, this animal was found within close proximity to Pine Snake 2006.34. It was observed to be opaque in an old metal gas tank on 07/16/08. This same gas tank was used by Pine Snake 2006.34 on 07/08/08. HA staff also noted an old black racer shed just outside of and along the exterior of the tank. These observations suggest that this location may serve as a shedding station for multiple snake species. This snake utilized a stump hole in a forested wetland from 08/21/08 to 09/07/08. On 10/03/08 both this animal and Pine Snake 2006.34 were relocated in the same hole near the glass dump pile, where 2006.34 eventually overwintered. However, 2007.14 spent only one relocation here and then moved approximately 1.6 km to the NE into a mammal burrow dug into the side of a large hunter's pit where it eventually overwintered. This den has been designated as NH AA.

**N. Pine Snake 2007.15** (♀). Current status = alive and healthy.

**2007:** This snake was originally captured in trap 8 on 08/17/07 along the perimeter drift fence on the south side of the construction site. HA decided that it was too late in the season to implant a transmitter, so an external transmitter was attached. The snake was released on 10/09/07. After its release, this animal stayed south of the construction site and was often relocated within sight of the perimeter drift fence. From 10/20/07 to 10/22/07 this animal was relocated underground at the base of the perimeter drift fence between traps 1 and 2. It eventually moved into the interior of the forest and hibernated in a stump hole (NH M) on privately owned upland oak/pine forest south of the site. Earlier in the season Field No. 2007.05 was relocated in the same stump hole.



**Figure 28.** Radiotelemetry locations and activity range (minimum convex polygon and 50% and 90% isopleth from kernel analysis) for pine snake # 2007.15. The area used while being radio-tracked in 2008 is 329.65 acres (133.4 hectares).

**2008:** This snake egressed from NH M on 04/23/08. It was relocated 91 times in 2008. It was collected on 05/05/08 to have the external transmitter removed and to be surgically implanted with a two-year transmitter. It was released on 05/15/08. This animal continues to use habitat directly south of the eastern portion of the SPR property, often being relocated within 10 meters of the perimeter drift fence line. On a number of occasions this animal 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 occasion was located on the shoulder of the southbound lane of the Garden State Parkway. Two interesting behaviors were exhibited by this animal in 2008. The snake was relocated both climbing and resting in trees on at least 2 occasions. (**Fig. 29**) It is uncertain if this was a predator-avoidance response or a foraging method. In addition, this animal was often located in and around mole tunnels on the forest floor. (**Fig. 30**) This may indicate a preference for a particular species of prey or an effective 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. This new location (NH X), is where 2007.15 is currently overwintering.



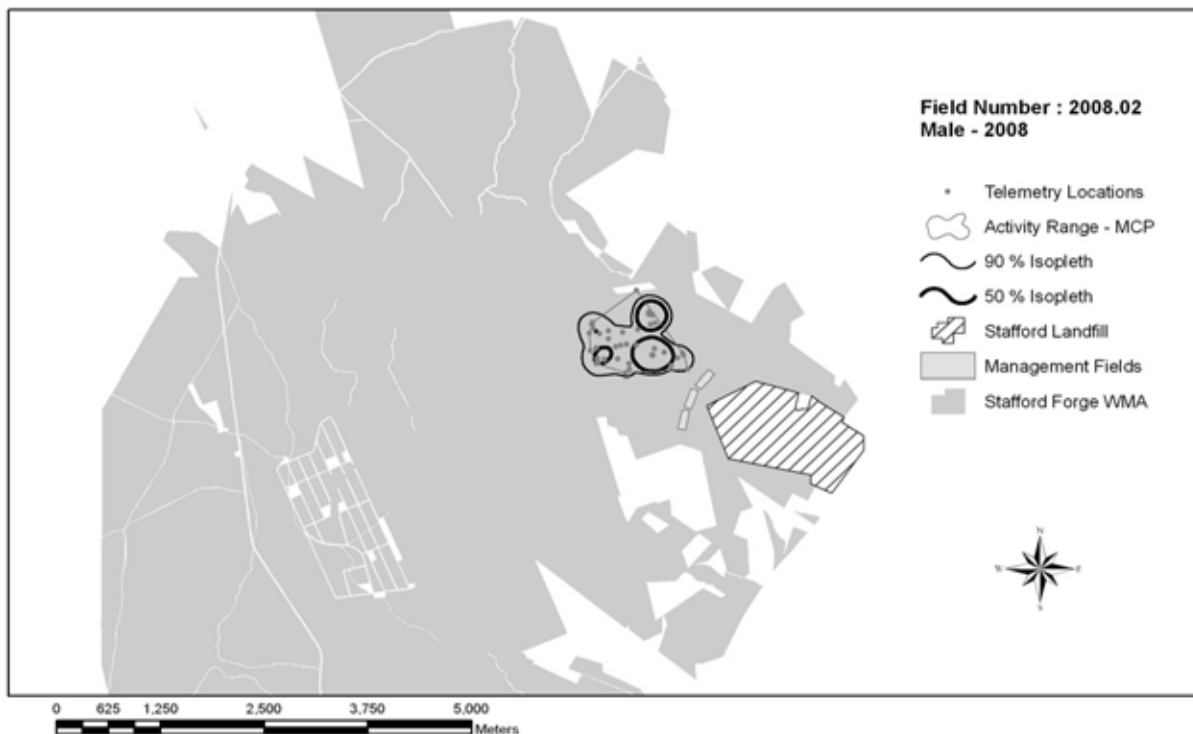
**Figure 29.** Pine snake 2007.15 stretched out across the branches of a small black oak. Photo by Robert Fengya, Herpetological Associates Inc, 2008.



**Figure 30.** Pine snake 2007.15 in mole burrow. Photo taken by Robert Fengya, Herpetological Associates, Inc. 2008.

**N. Pine Snake 2008.02 (♂).** Current status = alive and healthy.

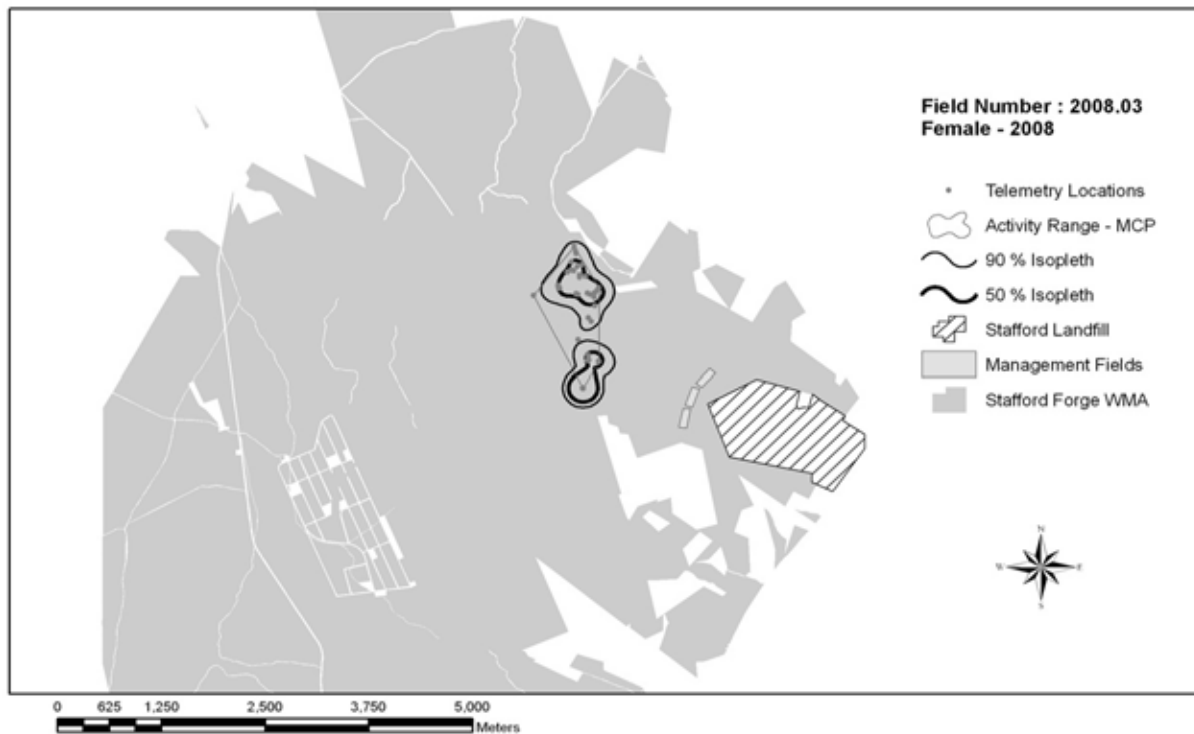
**2008:** This snake was originally captured emerging from NH C on 04/16/08. It was fitted with an internal two-year transmitter and released on 05/21/08. It was relocated 72 times in 2008. The first two weeks after release, the animal was found within close proximity to pine snake 2007.07, a female that also overwintered in NH C. In mid-July this snake made a significant move to the NE, 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. While using a debris pile in the area, the snake was observed in an opaque state (getting ready to shed its skin). On 08/21/08 it 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. The snake returned to the aforementioned pile of debris on 09/16/08 and once again was noted to be in an opaque condition. This suggests that this snake may be using the debris pile as a shedding station. On 09/25/08 this animal made another large move back to NH C where it is currently overwintering with pine snake 2007.07.



**Figure 31.** Radiotelemetry locations and activity range (minimum convex polygon and 50% and 90% isopleth from kernel analysis) for pine snake # 2008.02. The area used while being radio-tracked in 2008 is 193.11 acres (78.15 hectares).

**N. Pine Snake 2008.03 (♀).** Current status = alive and healthy.

**2008:** This snake was originally captured egressing from a corralled natural den, NH E, on 04/16/08. 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 Rd, and utilizing the Mill Creek wetland corridor for travel and cover. On 05/30/08 the snake was relocated outside of an active red squirrel burrow. The snake appeared to have a mid-body bulge, indicating that it had recently fed. On a number of occasions, this snake was relocated in the vicinity of red squirrel feeding stations/ burrows. This may be indicative of a specific prey preference or a successful foraging strategy. On 09/30/08, this snake returned to NH E where it is currently overwintering.



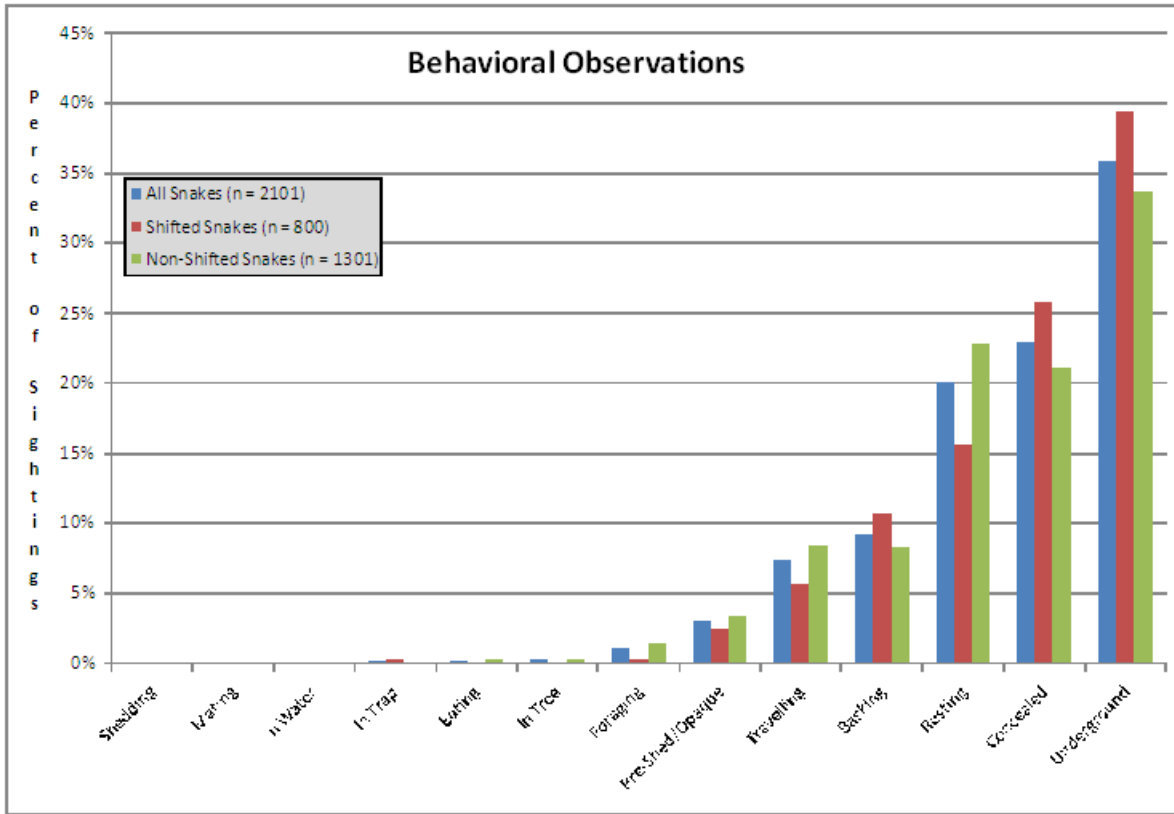
**Figure 32.** Radiotelemetry locations and activity range (minimum convex polygon and 50% and 90% isopleth from kernel analysis) for pine snake # 2008.03. The area used while being radio-tracked in 2008 is 198.81 acres (80.45 hectares).

## HABITAT USE AND BEHAVIORAL ANALYSIS

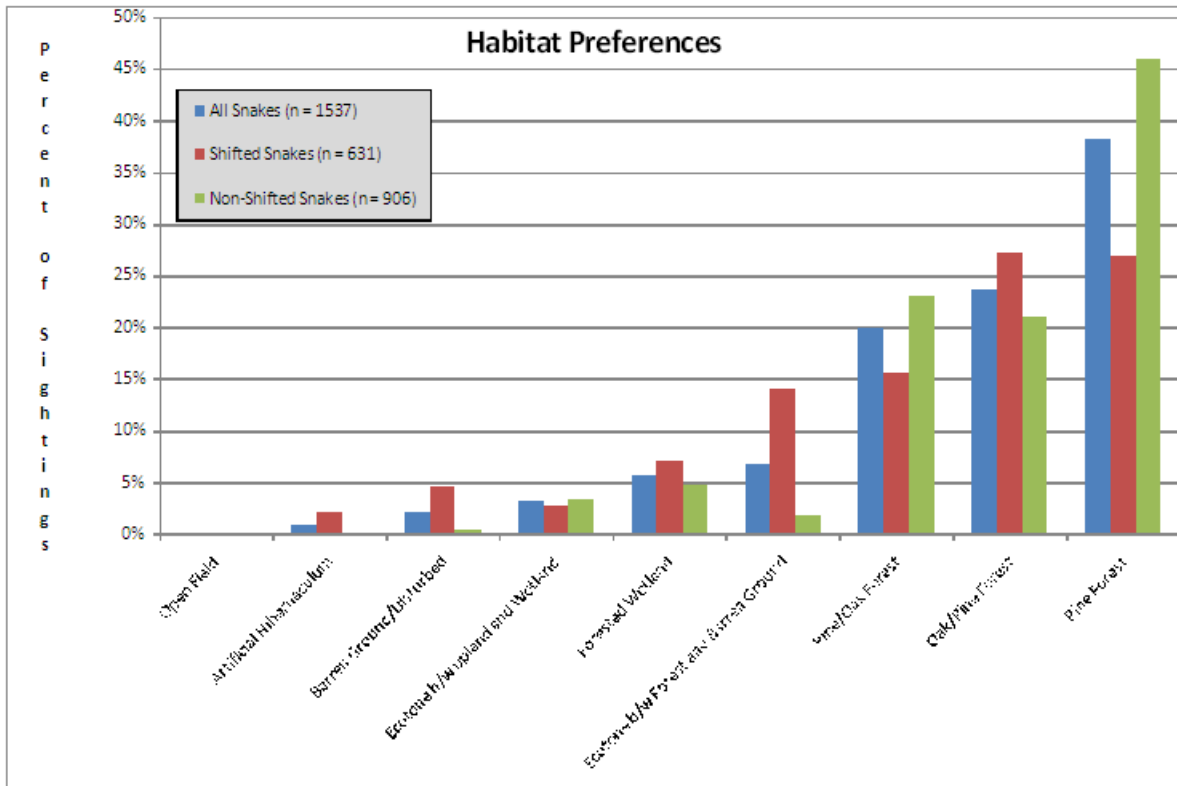
Radio-tracking and consistent monitoring of northern pine snakes revealed some interesting habitat use preferences, movements, and behaviors. One of the main questions to be answered by this investigation was to compare the behavior of the shifted snakes to the non-shifted radio tracked snakes. (Figures 33 and 34) show two graphs which provide a representation of habitat use and behavioral comparisons of shifted vs. non-shifted snakes in 2008. (Table 2) provides a breakdown of habitat types used by pine snakes. Habitat types used in 2008 are defined as follows: *Open Field* - open canopied, sandy fields often times dominated by various 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; *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.

Habitat Types	All Snakes (n = 1537)		Shifted Snakes (n = 631)		Non-Shifted Snakes (n = 631)	
	Number of Relocations	Percent of Total	Number of Relocations	Percent of Total	Number of Relocations	Percent of Total
Open Field	1	0.07%	0	0.00%	1	0.11%
Artificial Hibernaculum	13	0.85%	13	2.06%	0	0.00%
Barren Ground/Disturbed	32	2.08%	29	4.60%	3	0.33%
Ecotone Between Upland/Wetland	47	3.06%	17	2.69%	30	3.31%
Forested Wetland	86	5.60%	44	6.97%	42	4.64%
Ecotone Between Forest/Barren Ground	104	6.77%	88	13.95%	16	1.77%
Pine/Oak	306	19.91%	98	15.53%	208	22.96%
Oak/Pine	362	23.55%	172	27.26%	190	20.97%
Pine Forest	586	38.13%	170	26.94%	416	45.92%
Total Relocations	1537	---	631	---	906	---





**Figure 33.** Chart depicting the percentage of total pine snake observations from the 2008 Stafford Park Redevelopment Study where snakes exhibited particular behaviors.



**Figure 34.** Percentage of total pine snake observations from the Stafford Park Redevelopment Study where snakes were observed in particular habitats.

### **TREATMENT A SNAKES (ONE-WINTER, EXCLUDING 2006 HATCHLINGS):**

There were originally 12 snakes in the 'A' Treatment, nine of which were radio tracked. The other three animals were sub-adults (too small to radio track) and were PIT tagged, released into the one winter treatments in 2006, and released into the wild in 2007. One animal has died from this treatment group each year (2006, 2007, and 2008) from raptor predation, forest fire, and unknown causes, respectively. The remaining six animals were radio tracked throughout the 2008 active season. None of these snakes have returned to the management fields for overwintering in the 2008-09 season. They have all selected natural hibernacula within the surrounding forest that were newly identified or identified in the 2007-08 winter. Two animals, pine snakes 2006.09 and 2006.34 have returned to the same natural hibernacula they selected last winter. One snake (2006.26) is overwintering in a natural den (NH N) identified in the 2007-08 winter along with a non-shifted snake (2007.05). The remaining three snakes are in newly defined natural hibernacula.

### **TREATMENT B SNAKES (TWO-WINTERS, EXCLUDING 2006 HATCHLINGS):**

There were originally 9 snakes within the "B" Treatment. In fall 2006, four were predated upon by red-tailed hawks (pine snakes 2006.10, 2006.13, 2006.23, and 2006.27). In early spring 2007, one more animal (pine snake 2006.06) from this treatment group was killed by a hawk. In 2008, pine snakes 2006.20 and 2006.22 were determined to be deceased (see snake synopses for further data). This leaves two animals from the original group. Of these, one was a juvenile snake that could not be radio tracked. The other, pine snake 2006.29, continues to be part of the radiotelemetry aspect of the study. This animal selected a natural den (NH T) west of the management fields to overwinter this season.

### **TREATMENT C SNAKES (ONE WINTER IN HA LAB):**

There were originally 8 snakes in the 'C' Treatment. One died on 09/21/06 in HA's lab. HA staff performed a necropsy and found the transmitter located inside of the small intestine and determined this to be the cause of death. One snake's transmitter has failed prematurely (pine snake 2006.30) and, therefore, can not be relocated. Six animals continue to have functioning transmitters and are being radio tracked. Three of these snakes are currently overwintering on the management fields. Pine snakes 2006.16 and 2006.19 are in AH 1 and 2006.15 is using a mound in the middle of MF 2 for hibernation. Two Treatment C snakes (pine snakes 2006.08 and 2006.17) are using NH B, a natural hibernaculum located thirty (30) meters northwest of AH 6. One Treatment C snake (pine snake 2006.28) has made a significant move to habitat south of the SPR property where it has selected a new location to hibernate (NH S).

### **NON-SHIFTED PINE SNAKES**

In order to determine if the "shifted" snakes are behaving differently than they would if not shifted, a portion of the overall population (N = 12 snakes) was fitted with radio-transmitters so HA could monitor their behavior and compare their movements with the "shifted" pine snakes. Thus, the "non-shifted" snakes were radio-tracked to provide a direct comparison. Most were captured in 2007, but two of these snakes in the group were captured in 2008. All of these animals were captured using various survey techniques, including drift fence trapping, random opportunistic searching (ROS), time constrained searching (TCS), road cruising, and natural den corrals. All 'non-shifted' animals overwintered in natural dens located within their home ranges in the 2007- 2008 winter.

In the 2008-09 winter, five of these animals returned to the same overwintering sites used in the previous year (pine snake 2007.05, 2007.07, 2007.11, 2008.02 and 2008.03), six animals selected different locations (pine snakes 2007.03, 2007.04, 2007.09, 2007.10, 2007.14 and 2007.15), and one animal died (pine snake 2007.06).

#### **JUVENILE AND HATCHLING PINE SNAKES**

Very few 2006 hatchling snakes were recaptured during 2008. It is unknown how many of the hatchlings may have been killed and eaten by raptors or other predators. Likewise, it's also unknown how many hatchling pine snakes were killed during the May 16, 2007, forest fire. Due to the dismantling and removal of the corral walls in 2008, the possibility of recapture of these snakes is markedly reduced. The hatchlings that did survive are now dispersed into the surrounding forested habitat. Of the ten pine snake hatchlings recaptured in 2007, none of these were observed in 2008. This is not uncommon, as juvenile pine snakes are secretive and seldom encountered in the woods (Fukada 1978; Fukada 1960; Fitch 1999). HA captured and PIT tagged eleven new hatchling/yearling pine snakes in 2008. Nine of these snakes were from a nesting/denning location (Natural Hibernaculum "H") south of the SPR property within Stafford Forge WMA. The first was captured on 04/18/08 while conducting a time-constrained search near NH H. On 09/02/08, HA staff observed a hatchling pine snake retreat into a previously undetected nest chamber approximately five meters from NH H. Upon further inspection HA staff noted three hatched pine snake eggs on the surface. Due to evidence of digging at the nest site by a mammal, HA attempted to locate the nest chamber in order to protect any hatchlings or eggs from further predation efforts. Upon excavation, two hatchling snakes, five unhatched eggs and three hatched eggs were found. In addition, several old hatched pine snake eggs from a previous year's clutch were recovered. The nest chamber was then rebuilt and covered. The clutch was withheld in HA's SPR office until all 5 eggs hatched and the snakes shed. They were then processed, PIT tagged, and released into the entrance to NH H. The eggs and shed skins were buried at the approximate location of the nest site. On 09/20/08, HA staff captured another hatchling pine snake on the surface near the NH H entrance hole. This animal is suspected to be the eighth hatchling from the clutch, as three hatched eggs were initially found, but only two hatchling snakes.

The other two 2008 hatchling/juvenile snake captures were on and within the immediate vicinity of the SPR property. One was captured within the AH 4 enclosure. This was a yearling from a clutch identified in 2007 (laid by pine snake 2007.05). The other, a yearling/juvenile snake, was captured in the perimeter drift fence line attempting to leave the property on 10/20/08. The trap was near where Hay Road intersects the trap line. Due to the lack of available habitat within the Stafford Park property, HA believes that the animal traveled onto the site, prior to being captured, through the gap in the fence line at the road. It is not known from where this animal may have originated.



## USE OF MANIPULATED AND ENHANCED HABITAT

In the 2008 field season, the management fields were used extensively by pine snakes and other wildlife species. Ten radio-tracked and two unmonitored pine snakes were documented using the perimeter earthen berms for shelter, foraging and shedding stations throughout the active season. Two female pine snakes were observed using the management fields for nesting in 2008. One female, pine snake 2007.05, excavated a nest chamber and laid eggs in the perimeter earthen berm behind AH 3 in MF 2. Another female was observed excavating a nest chamber at the base of a large mound in the center of MF 2. Although this female was a new snake, she was not captured and PIT tagged to minimize disturbance. HA staff did not want to discourage her from nesting. Detailed morphological notes and photographs were taken to re-identify this snake if found again. Cover boards were placed around the nest entrance holes in an attempt to capture and document hatchling snakes emerging from the nests. In early September, HA staff found evidence of a predation attempt by a small mammal at one of the nests (**Fig. 35**). Small tracks and digging in and around the nest hole was noted. HA searched the nest chamber for hatchling snakes, but found none. Six successfully hatched pine snake eggs were recovered (**Fig. 36**). It is uncertain if any of these hatchlings were predated or if they eluded the mammalian predator. No hatchling snakes were recovered from either nest site.

## ENVIRONMENTAL AND MANAGEMENT FIELD MONITORING

### Environmental Monitoring

Most of the habitat alteration, disturbance and landfill construction on site was conducted in 2007. HA monitored all clear cutting of the forest, stump removal and soil stripping in the center portion of the site near the water tower in November, 2008. No animals were found during these activities. Likewise, during the pine snake nesting season (mid June - early July) HA monitored the application of clean fill to the uncapped portion of the landfill. This was done in order to locate any nesting attempts by female pine snakes on the open, sandy area. No nests, evidence of nesting, or pine snakes were found during routine monitoring within the redevelopment portion of the property.

### Management Field Monitoring

While on-site habitat alteration was minimal in 2008, maintenance of the management fields and monitoring of the dens for snake activity were important aspects of the 2008 season. In early spring, traps along the corral walls were checked on a daily basis. After the completion of spring egress period (mid-March to the end of April), all corral walls were dismantled to allow uninhibited movement to and from all artificial dens. The netting over four of the dens was damaged by wind, snow, ice weight, and general bad weather. These nets were taken down and discarded. Nets over AH 1 and AH 5 still remain. Regular searches of the artificial den areas for hatchling, juvenile and new pine snakes during the active field season were conducted. HA staff also monitored the management fields to discourage and prevent trespassing. HA did not observe any evidence of trespassing or tampering in 2008.



**Figure 35.** Pine snake 2007.05's nest after predation attempt by a small mammal. Photo by Robert Fengya, Herpetological Associates, Inc. 2008.

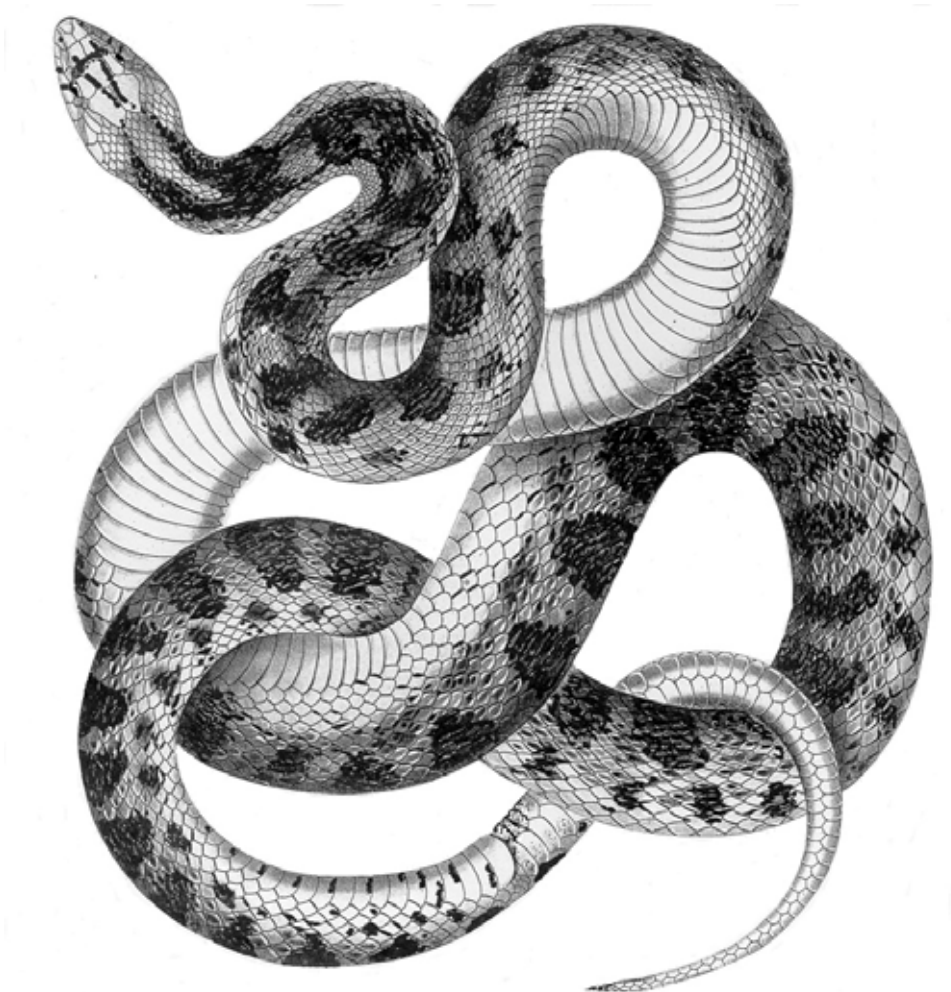


**Figure 36.** Closeup of six successfully hatched pine snake eggs outside of 2007.05's nest after predation attempt. Although HA staff searched in and around the nest, no hatchling pine snakes were recovered. It is not known if any hatchling snakes were predated on or if they were able to elude the mammalian predator. Photo by Robert Fengya, Herpetological Associates, Inc. 2008.

## CORRALLING OF NATURAL HIBERNACULA

Pine snakes will often den communally (Burger et al 1988b). In an attempt to capture new pine snakes, HA corralled selected locations that free roaming pine snakes used as overwintering locations in the 2007-08 winter. Six foot metal stakes and four foot tall, 1/4 inch metal mesh, hardware cloth were used to construct the temporary enclosures. They were erected in February and March 2008 and were dismantled shortly after spring emergence in May and June. Not all natural hibernacula were corralled due to either inaccessibility or their proximity to roads.

A total of 8 natural hibernacula were corralled. Of these, three (NH C, NH E, and NH G) yielded new pine snakes (HA Field No's. 2008.02, 2008.03, and 2008.04), along with 3 northern black racers (*Coluber c. constrictor*). HA will conduct similar corraling techniques in February/March 2009 to locate new pine snakes. A total of 28 confirmed natural den locations have been identified by HA within the habitat surrounding the SPR property, including Stafford Forge WMA and privately owned parcels in 2007 and 2008.



## DISCUSSION

### WINTER AND SUMMER DEN USE

Two adult study snakes from Treatment “C” (snakes that overwintered in HA’s lab in 2006) returned to one of the artificial hibernacula to overwinter this year. These two snakes were released into artificial hibernaculum 1 on 04/03/07 and returned to this same hibernaculum to overwinter. None of the one winter Treatment “A” snakes, or two-winter Treatment “B” snakes, or Treatment “C” snakes returned to the artificial hibernacula to overwinter in 2008-09. 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). In this study, all radio-implanted pine snakes are excluded from the Stafford Park property by the perimeter drift fence. However, two free-roaming snakes have breached the fence and gone back into the redevelopment portion of the property. Although some individuals from the population were forced to hibernate successfully in artificial dens, when they had the opportunity to return to their natural dens, they did so. These adult pine snakes have learned the surrounding habitat that is available to them, thus they have a high probability of important habitat recognition via chemical scent trails. All of these adult snakes from the one and two winter treatments may have previously overwintered in the various natural hibernacula discovered by radio-tracking. These winter dens that were located in the surrounding habitat were known to the snakes prior to the commencement of this study. It is likely that many of these animals have returned to these previously used den sites. This does not mean that (in the future) the artificial hibernacula will not be utilized as overwintering sites. Other artificial hibernaculum 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 artificial hibernacula constructed by HA in Stafford Forge WMA will most likely become an important and integral part of the habitat used by the study snakes and others as well.

The den corral walls previously enclosing the artificial hibernacula have been dismantled in 2008. Temporary corraling may be used to capture snakes upon spring emergence. This will help in quantifying den usage in the years to come. Otherwise, these hibernacula will remain unrestricted for pine snake use.

### USE OF ENHANCED OR MANIPULATED HABITAT

The Department’s Division of Land Management seeded the management fields with a native, warm-season grass mixture on June 1, 2008. The seed was provided by Walters. It was drill-seeded into the mineral soil with no lime or fertilizer. The grasses and other vegetative growth in 2008 was slow, yet steady (**Figures 37 and 38**). Warm-season grasses often take three or four growing seasons to truly establish (Ted Gordon, personal communication). These fields will provide more cover and prey availability for pine snakes as the seed stock and grassy vegetation becomes thicker. Open fields provide canopy free habitat for thermoregulation and also attract seed eating small mammals and birds, potential prey items for pine snakes.

A total of 12 radio-tracked pine snakes were observed using the management fields to some extent in 2008. Most of these behavioral observations were of snakes using the perimeter earth berms for concealment. Pine snakes were not the only wildlife observed utilizing these structures. Many different species of reptiles and amphibians including black racers, eastern hognose snakes, fence lizards, and Fowler’s toads were observed in, on, or near these structures.



**Figure 37:** Photograph of management fields shortly after DEP's division of land management seeded them with native warm-season grass mixture. Photograph by Michael J. McGraw, 2008 Herpetological Associates, Inc.



**Figure 38:** Photograph of the native grass species later in the 2008 season. Photograph by Michael J. McGraw, 2008 Herpetological Associates, Inc.



The earth berms and log piles also provide ideal habitat for prey items such as white-footed mice, meadow voles, red-backed voles and red squirrels. Another intended goal for the management fields is to provide suitable nesting habitat for pine snakes. In 2008, two female pine snakes were confirmed using the management fields for the purpose of nesting. One female, a non-shifted radio-tracked animal, used the east facing portion of the perimeter earthen berm while a new female pine snake was observed nesting on the ESE edge of an earth mound in the middle of MF 2. HA will conduct time-constrained searches for nesting evidence and behavior in the management fields each year for the duration of this investigation.

## **BREEDING AND NESTING OBSERVATIONS**

Through intensive monitoring, HA observed both breeding and nesting behavior of individual snakes within the study population in 2008 (**Figures 39, 40, 41**). Below is the description of a breeding observation made on 05/21/08, as described by HA Field Biologist, Robert Fengya:

“When encountered, pine snake 2007.05 was laying outstretched in front of the burrow she was radio-tracked to during relocation No. 16. A new male pine snake approximately 125 to 150 cm in length was completely draped over the female dorsally, and was slowly writhing over 2007.05 while she remained motionless. 2007.05 began to move forward slightly, then was immediately bitten and held by the male snake on a 90 degree angle on the left side of her head and was immobilized. The male rapidly began a process of tactile search/ tail alignment, attempting to raise the female’s tail with his own. This maneuver was successful, with both tail regions raised four to five inches off of the ground; 2007.05's cloaca opened slightly. In a rapid forward motion following the underside of the female’s tail with his own, the male slid his tail in a downward thrust and actual copulation began at 11:02 AM. The pair remained nearly motionless for 38 minutes, save for occasional twitches and slow writhing motions. The male retained his bite-hold on 2007.05 throughout the copulation. At 11:40 AM, the male withdrew its hemipenis and released its bite on the female, who almost immediately crawled forward into a hole beneath a nearby log. The male crawled slowly in a 7-10 foot circle around the area with its tail raised and cloaca pressed to the ground, apparently attempting to clean itself or perhaps engaging in some type of scent-marking territorial behavior. This completed, the male settled into a loose coil around a small clump of scrub oak less than 1 meter away from the burrow the female had entered. A total of 17 minutes of courtship was observed, followed by 38 minutes of copulation.”

No other breeding observations were observed in 2008. This behavior is rarely observed in the wild.

Two separate nesting behaviors were observed in 2008 as well. The radio-tracked female in the above breeding description (pine snake 2007.05) made a significant move northwest, traveling approximately 1.2 miles in two days to MF 2 to lay her eggs. This move began 27 days after the breeding observation. This snake may have been searching for the old landfill (the former nesting area), but when it entered MF 2, she recognized it as suitable nesting habitat. This female is a non-shifted snake whose home range (previously determined through radiotelemetry from 07/17/07 to 06/17/08) consisted of the forest south and east of the management fields. Upon original capture on 05/28/07, this animal was gravid. She was temporarily placed in the AH 4 enclosure to deposit eggs prior to transmitter surgery. After egg deposition, she was then collected, brought to the HA laboratory in Jackson, New Jersey for transmitter implantation surgery, and released at the original capture site within her home range.



**Figure 39.** Female pine snake 2007.05 being immobilized during copulation by an unmarked male pine snake with a 90 degree bite to the head. Photo by Robert Fengya, Herpetological Associates, Inc. 2008.



**Figure 40.** Closeup of copulation between female pine snake 2007.05 and an unmarked male. Note the extended hemipenis of the male. Photo by Robert Fengya, Herpetological Associates, Inc. 2008.



**Figure 41.** Pine snake 2007.05 coiled at the entrance to the nest she excavated in the earth berm along western edge of management field 2. Photo by Robert Fengya, Herpetological Associates, Inc. 2008.

It is unknown how or why this snake chose to make such an isolated movement to a recently modified area. However, this observed behavior suggests the usefulness of creating fields with respect to management of habitat for pine snakes. As previously mentioned, an unmarked (“new”) female pine snake was also observed excavating a nest chamber on a man-made earth mound in MF 2 on 06/20/08, further supporting the importance of creating field habitat for snake management. As HA continues to conduct this long-term radiotelemetric study, attempts will be made to further document behavioral events and movement patterns in an attempt to gain a better understanding of the life history of pine snakes with the intention of advancing conservation methodologies.

## RESEARCH QUESTIONS AND FUTURE GOALS

As stated in the introduction section of this report, there are 6 questions that the Department and HA will attempt to answer as part of this long-term study. After our second year of this study, we have a hint towards some answers, while new questions arise. In order to scientifically provide answers they must be supported by a significant data set. Below are some preliminary responses to the 6 questions with only two years of data.

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?

**Yes.** Through forced denning in the one and two-winter treatments, HA observed that pine snakes of varying age classes could successfully overwinter in artificial hibernacula. Currently there are two adult pine snakes (from the C treatment snakes) confirmed using AH 1 to overwinter. These two snakes spent the winter of 2006/07 in HA’s lab and were released into AH 1 (a two winter treatment) in the spring of 2007. Since the artificial den corral walls were removed this past spring, these snakes were free to select new denning locations, but still returned to AH 1 at the end of the active field season. It will require more years of study to fully determine if these snakes have established themselves in the artificial den. HA will attach traps to the artificial den entrances in the spring to further determine whether any other pine snakes utilized the dens this winter.

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?

**Unknown.** It is too soon to know the answer to this question. This is the first winter that the corral walls have not limited movement to and from the artificial hibernacula. HA will trap the den entrances during the spring egress to determine if any wild (non-study individual) snakes or un-monitored (juvenile and hatchlings from the study) snakes used the dens for overwintering.

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?

Based on 2008 data, it appears that the shifted group of pine snakes have used smaller average home ranges (MCP = 138.9 acres, Kernel = 160.3 acres) than the non-shifted group (MCP = 378.4 acres, Kernel = 271.1 acres) (**Figures 5 and 6**). Within each group, however, the difference in home range size between sexes is minimal (**Fig. 7**).

One major difference in behavior noted during the 2008 season is the percentage of relocations where members of each group (shifted versus non-shifted) were observed underground. In 2007 non-shifted snakes were relocated over twice as often underground (45.0% of all observations) as shifted snakes (22.0% of all observations). However in 2008, the shifted snakes were relocated underground a higher percentage of the time (39.4% of all observations) than non-shifted snakes (33.7% of all observations). The percentage of time spent underground nearly doubled for the shifted snakes in 2008 compared to 2007. Another major behavioral difference observed between the two groups of snakes during the 2008 season, as compared to the 2007 season, is the amount of time spent resting between the two groups. In 2007 shifted snakes were relocated 25.0% of the time resting as compared to non-shifted snakes (6.0% of all observations), however, during 2008, the non-shifted snakes were observed a greater amount of time resting (22.8% of all observations) than the shifted snakes (15.6% of all observations). However, it is important to note that there is an inherent subjectivity in the selection of the behavioral category of “resting”. The significance, if any, of the difference in percentage of resting observations between the two different groups of snakes during the 2007 and 2008 seasons is not yet 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 future year end and final reports.

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?

**Inconclusive.** In 2007, two radio-tracked snakes entered the SPR property. Captures were also made in the perimeter drift fence of snakes attempting to enter the site. In 2008, only one radio-tracked pine snake entered the site at the property line between 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.

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?

**Inconclusive.** This is the first winter that all radio-tracked study snakes are unrestricted in their movements and had the ability to select their own den locations. Unfortunately, the loss of many of the snakes from Treatment B will undoubtedly influence the results of this two treatment comparison. It is too soon in this study to completely answer this 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?

**Yes.** In 2008, HA observed and documented two separate females (one non-shifted, one new snake) using the management fields for nesting. It is possible that other non-radio-tracked female pine snakes could have also nested on one of the three management fields, but went undetected by HA staff. Nesting behavior will be monitored intensely in 2009.

## CONCLUSION

Pine snakes (adults, subadults, and hatchling) can successfully overwinter in the artificial dens designed by HA. Two pine snakes from 'C' treatment have returned to an artificial hibernaculum and are currently overwintering there. Another snake from the 'C' treatment is overwintering in an earth mound in MF 2. It remains to be determined whether these snakes and/or other study animals will return to use the enhanced habitat in subsequent years. HA will closely monitor the six artificial dens for use by the pine snakes, as well as other snake species over the next five years.

MCP and Kernel home range analysis has determined a marked difference in spatial usage between shifted and non-shifted pine snakes. Early data suggests that the average home range for the non-shifted snakes was larger than that of the shifted pine snakes. This is contrary to the findings of Reinert (1999), where he radio-tracked translocated timber rattlesnakes to find that translocated snakes had significantly larger home ranges. However, it should be noted that our study pine snakes were not moved out of their home ranges, just shifted within their activity areas and forced to stay in artificial dens for one or two winters. Additional studies may show larger movement trends in the home range fidelity of the shifted snakes versus the non-shifted snakes who have shown larger activity ranges in 2008. The following five years of radio-telemetry will further demonstrate if these two groups of pine snakes have significantly different home ranges.

### *Fidelity to Overwintering Dens*

For the purpose of this analysis, den site fidelity is described as a pine snake that returned to the same den location two years in a row. By comparing the 2007 and 2008 data, the percentage of den site fidelity in non-shifted snakes (41.6%) is greater than that of the shifted snakes (25%). This was the first winter season that all shifted (Treatments A, B, and C) snakes and non-shifted snakes chose their overwintering sites unrestricted. This comparison will be better answered upon the completion of the radiotelemetry study. It is still uncertain if habitat imprinting from the one and two-winter treatments has encouraged the use of the artificial hibernacula or not. This also will be better understood upon the completion of the study.

In 2008, one radio-tracked adult pine snake and one non-radio-tracked gravid female pine snake entered the Stafford Park property. The radio-tracked adult pine snake used an existing strip of forested habitat between the Garden State Parkway and the Costco building. One hatchling pine snake was captured attempting to exit the site along the northern property line as well.

All study animals are free roaming henceforth. A comparison of the one-winter, two-winter, and 'C' treatments has begun using the 2008 field season data. Over the next five years HA will continue to determine if these animals show any difference in den site fidelity with respect to the artificial dens. Due to mortalities from predators, forest fire and poor health due to surgery, the 'B' Treatment (two-winter snakes) is represented by only one radio-tracked animal in 2008.

In 2008, unrestricted denning and nesting behavior by northern pine snakes has been observed within the management fields. Over the next five years of intensive radio-telemetry and visual survey methods, HA will further determine the suitability of this enhanced habitat for critical behavior (denning and nesting). The use of the management fields and nesting behavior is expected to continue, based upon similar pine snake studies at the Audubon Sanctuary in western Berkeley Township of Ocean County (Robert Zappalorti, personal observations).



# Appendices



# Appendix 1

<b>Appendix 1.</b>			
<b>Hibernaculum Designation</b>	<b>Snakes that denned in hibernaculum in 2007</b>	<b>Snakes that denned in hibernaculum in 2008</b>	<b>Description of Hibernaculum</b>
AH 1	2006.16, 2006.19, 2006.22, 2006.28	2006.16, 2006.19	Artificial hibernaculum created by Walters using HA's design. Located on south side of MF 1.
AH 2	None Known	None Known	Artificial hibernaculum created by Walters using HA's design. Located on north side of MF 1.
AH 3	None Known	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	Artificial hibernaculum created by Walters using HA's design. Located on north side of MF 2.
AH 5	None Known	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	Artificial hibernaculum created by Walters using HA's design. Located on north side of MF 3.
NH A	2006.26, 2006.11	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	Large mammal burrow in pine forest approximately 70 meters NW of AH 6.
NH C	2007.07, 2008.02	2007.07, 2008.02	Large mammal burrow in upland pine forest in SFWMA west of management fields.
NH D	2006.32	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	Large mammal burrow in upland pine forest in the interior of SFWMA.
NH F	2007.09	None Known	Non-descript hole in upland pine forest in interior of SFWMA.

<b>Table X.</b> (Continued)			
<b>Hibernaculum Designation</b>	<b>Snakes that denned in hibernaculum in 2007</b>	<b>Snakes that denned in hibernaculum in 2008</b>	<b>Description of Hibernaculum</b>
NH G	2007.14	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	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	Non-descript hole in upland oak/pine forest approximately 1.1 kilometers N/NW of management fields.
NH J	2007.10	None Known	Small non-descript hole in upland oak/pine forest approximately 1.7 km north of management fields within SFWMA.
NH K	2006.21	None Known	Small non-descript 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	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	Stump hole in privately owned upland oak/pine forest south of the SPR site.
NH N	2007.05	2007.05, 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	Small non-descript hole in upland oak/pine forest approximately 1.3 km S/SW of the SPR site.
NH P	2007.06	None Known	This was an unsuccessful attempt by the snake to excavate it's own overwintering spot. Snake's carcass was found only a few inches under the surface in the spring of 2008.

<b>Table X. (Continued)</b>			
<b>Hibernaculum Designation</b>	<b>Snakes that denned in hibernaculum in 2007</b>	<b>Snakes that denned in hibernaculum in 2008</b>	<b>Description of Hibernaculum</b>
NH Q	None Known	2006.11	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	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	Location is in pine/oak forest a considerable distance SW of the SPR site. No obvious entrance holes into denning site were noticed.
NH T	None Known	2006.29	Den location is in upland pine forest west of the management fields.
NH U	None Known	2007.04	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	Non-descript hole in oak/pine forest south of the SPR site. Location is approximately 7 meters from where this snake overwintered last year.
NH W	None Known	2006.32	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	Mammal burrow only apprx. 160 meters south of the drift fence along the southern portion of the SBR site near the Costco building.

<b>Table X. (Continued)</b>			
<b>Hibernaculum Designation</b>	<b>Snakes that denned in hibernaculum in 2007</b>	<b>Snakes that denned in hibernaculum in 2008</b>	<b>Description of Hibernaculum</b>
NH Y	None Known	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	Small non-descript hole in same tract of upland oak/pine forest that the snake hibernated in last year.
NH AA	None Known	2007.14	Large hunter's pit/mammal burrow in upland pine forest approximately 1.6 km SW of MF 1.

# Appendix 2

## Appendix 2. Dead Snake Synopsis:

***N. Pine Snake No. 2006.06 (♂).*** Current status = Deceased. 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.

***N. Pine Snake No.2006.07 (♂).*** Current status = Deceased. 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 wrapped around the small intestine of the snake and this was determined to be the cause of death.

***N. Pine Snake No. 2006.10 (♂).*** Current status = Deceased. 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. On 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. They both flushed, perched in nearby trees, and 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.

***N. Pine Snake No. 2006.12 (♂).*** Current status = Deceased. 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.

***N. Pine Snake No. 2006.13 (♂).*** Current status = Deceased. 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.

***N. Pine Snake No. 2006.18 (♂).*** Current status = Deceased. 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 this first relocation. The snake was killed in the fire on 5/16/08. The snake's charred corpse was found in the same area on 05/17/07.

***N. Pine Snake No. 2006.23 (♀).*** Current status = Deceased. 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.

***N. Pine Snake No. 2006.27 (♀).*** Current status = Deceased. 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.

***N. Pine Snake No. 2006.31 (♀).*** Current status = Deceased. 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.

***N. Pine Snake No. 2007.02 (♂).*** Current status = Deceased. 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.

***N. Pine Snake No. 2007.08 (♂).*** Current status = Deceased. This large male snake was originally captured by HA staff in a heavily burnt pine forest on 6/04/07 while random searching. 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.



***N. Pine Snake No. 2007.12*** (♀). Current status = Deceased. This female snake was relocated 9 times during the 2007 field season. It was found concealed inside an abandoned motorcycle gas can 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.

***N. Pine Snake 2007.13*** (♀). Current status = Deceased. 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 (See 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.

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