INTRODUCTION

In keeping with the June 28, 2006, "Memorandum of Agreement" (MOA) between Walter's Homes, LLC (hereafter Walter's), Stafford Township, Ocean County and the New Jersey Pinelands Commission (hereafter the Commission) . Walter's has initiated the remediation of two old landfills and the construction of a new legal landfill. As part of the remediation, they will also construct a mixed use commercial and residential development, known as the Stafford Business Park Redevelopment Project (hereafter SBP), in Stafford Township, Ocean County, New Jersey (**Figures 1** and **2**). The SBP subject property is 388 acres in size. The New Jersey State-threatened northern pine snake (*Pituophis m. melanoleucus* - hereafter pine snake) occurs on, and in the vicinity of the property. As part of this development, Walter's has agreed to clean up various landfill areas on site; cap the existing main landfill; create three (3) pine snake habitat management fields, containing six (6) artificial overwintering hibernacula (hereafter dens); translocate a population of pine snakes; and initiate a seven (7) year pine snake monitoring program.

BACKGROUND INFORMATION

Threatened and endangered species surveys commenced on the site of the proposed SBP in April 2004. These surveys, which were conducted by EcolSciences, Inc., revealed the presence of several State-listed species, including pine snake on the proposed SBP site. Considerable effort was spent surveying the SBP site for pine snakes during the 2004, 2005, and 2006 activity seasons. Herpetological Associates, Inc. (hereafter HA) was asked to help with the pine snake research in May of 2006. Through these intensive surveys it was found that the SBP site was providing critical foraging, nesting, and over-wintering habitat for northern pine snakes. It was determined that pine snakes on the SBP site needed to be managed and studied.

Walter's was permitted to proceed with the SBP redevelopment 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 that are being addressed in two separate reports. These conditions were outlined in the June 28, 2006 MOA. HA and Dave Golden, senior Zoologist with the NJ 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 SBP site. In accordance with the MOA, all funding for the conservation plan is provided by Walters Homes, Inc. 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:

Part I:

The primary objective of the study plan are 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 offset the loss of pine snake foraging, nesting, and denning habitat through enhancement at the Stafford Forge Wildlife Management Area (WMA), which is within the known activity range of the pine snake population. Stafford Forge WMA was selected because it has highly suitable habitat and is within the home range of the pine snakes. It is also fully protected Pine Barrens habitat by the New Jersey DEP.

Part II:

The seven-year long-term monitoring program will also evaluate whether the pine snakes moved 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 moved to a different area within their known activity range?

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?

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 moved 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. 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?

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?

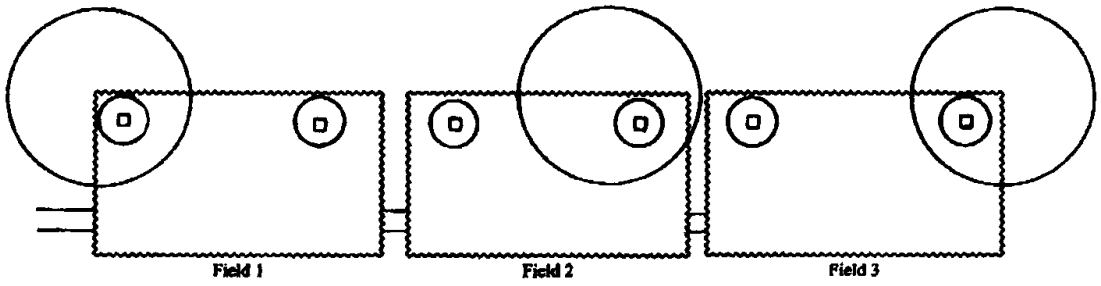
CREATION OF MANAGEMENT FIELDS AND ARTIFICIAL DENS

The relocation and management phase of the conservation plan included habitat manipulation for pine snakes that were removed from the SBP redevelopment site. HA supervised the creation of three (3) pine snake management fields at pre-selected suitable sites within Stafford Forge Wildlife Management Area. Each cleared field measures approximately 300 feet by 800 feet in size (or about 5.5-acres). These three 5.5-acre fields are meant to replace the open canopied grassland habitat that was lost on the SBP redevelopment site (e.g., the old landfill).

Two snake dens (artificial hibernacula) were constructed on each field, approximately 300 feet from one another. Each hibernaculum was encircled with a 1-acre fence to keep the snakes within the close vicinity of the dens. Three of the dens (1, 4, and 6) had a larger, 3-acre perimeter fence for holding the pine snakes over a twenty month period (1.5 years). Snakes egressing from these dens, known as two-winter treatments, were to be released into the 3-acre corrals. Snakes egressing from dens 2, 3, and 5, one winter-treatments, were to be allowed to disperse into the surrounding Stafford Forge Wildlife Management Area.

A total of ninety-five snakes were released into the dens in the Fall of 2006 (i.e., twenty adults, four sub-adults, and seventy-one hatchlings). These animals were randomly selected for distribution within six Treatments A and B (A = one winter and B = two winter treatments, respectively). 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 fall 2006. Unlike Treatments A and B, snakes were non-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 March 2007 and were monitored via radiotelemetry through the 2007 activity season. For more detailed information on all study animals please refer to the snake synopsis and home range analysis section of this report.

Figure 3. Layout of the Northern Pine Snake Management Fields, Artificial Hibernacula, and Fences at Stafford Forge Wildlife Management Area, Ocean County, New Jersey.



Legend: □ = Artificial Hibernaculum, ❍ = 1-acre Winter Fence, ◯ = 3-acre Summer Holding Corral.

Note: Diagrammatic drawing is not to scale. See description of Habitat Preparation and Manipulation 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 earth berms along the edges and large debris piles within the fields. These earth berms were constructed out of logs, sand, and brush. The fields provide pine snakes with forest-edge habitat suitable for basking and resting. The fields also allow for open, sandy, canopy-free potential nesting habitat for female pine snakes.

HA planted grasses on the soil to mimic native field type habitat. Native fields are proven to be good nesting and foraging habitat for northern pine snakes. For greater detail on the success of the habitat enhancement, please refer to the discussion section of this report.

SURGICAL COMPLICATIONS, HAWK PREDATION, AND FOREST FIRE

During the 2006 and 2007 field seasons, HA experienced some unforseen setbacks related to the pine snake study at the SBP site. These problems came in three different categories, such as, surgical complications with snakes implanted by EcolSciences, excessive hawk predation before bird netting was placed over the corrals, and a major forest fire last year on May 16, 2007. All these issues have had an adverse effect on the original approved study plan.

Surgical Complications

All snakes with 2006 field numbers were implanted by a veterinarian hired by EcolSciences, Inc. During late summer 2006, HA staff experienced problems with several transmitters implanted in the 2006 snakes. HA herpetologists weighed, measured, and assessed the general health of all study snakes upon initial assumption of environmental consulting responsibilities at SBP. Upon doing so, HA found a number of snakes to have transmitter migration problems due to improper implantation. The transmitters appeared to be moving freely throughout the body cavity, potentially causing serious health problems.

HA found a total of eight (8) study pine snakes having migrating transmitters. These snakes were taken to a veterinary hospital to be x-rayed and examined by a veterinarian and HA staff. Snakes, whose transmitters were found to be putting them at risk of injury or death, underwent corrective surgery. The following is a table listing all study animals that were implanted in 2006 and have experienced transmitter problems since implantation. For even more detail on each snake please refer to the snake synopsis section of this report.

Table 1. History of the eight pine snakes with migrating radio-transmitters.

Field Number	Frequency Number	Snake/Transmitter Status
2006.07	150.114	Snake is deceased due to transmitter migrating into its intestine. Died of internal complications.
2006.08	150.063	Snake spent the 2006-2007 winter in HA's lab due to poor health. Snake is currently over-wintering in HA's lab due to continuing problems with transmitter migrations.
2006.15	150.244	Snake spent the 2006-2007 winter in HA's lab due to poor health. It's transmitter failed sometime after being released into Den 4 prior to active field season. This snake is currently over-wintering in Den 4.
2006.16	150.204	Snake spent the 2006-2007 winter in HA's lab due to poor health. Currently the snake is in good health and the transmitter is functioning properly. This snake is over-wintering this year in Den1.
2006.17	150.224	Snake spent the 2006-2007 winter in HA's lab due to poor health. Currently the snake is in good health and the transmitter is functioning properly. This snake is over-wintering this year in Den 6.
2006.19	150.104	Snake spent the 2006-2007 winter in HA's lab due to poor health. Eventually the transmitter was removed because of health concerns. This snake is currently over-wintering in Den 1.
2006.28	150.463	Snake spent the 2006-2007 winter in HA's lab due to poor health. Currently the snake is in good health and the transmitter is functioning properly. This snake is over-wintering this year in Den 1.
2006.30	150.663	Snake spent the 2006-2007 winter in HA's lab due to poor health. Snake's transmitter failed on 06/01/07. This snake is over-wintering this year in Den 4.
2006.31	150.765	Snake spent the 2006-2007 winter in HA's lab due to poor health. Snake was killed in the forest fire after being released into Den 4.

Source: HA Data Base.

Hawk Predation

Six adult pine snakes were predated upon by red-tailed hawks (*Buteo jamaicensis*) from within the artificial den walls (Mike McGraw, pers. obs.). Of these, four snakes were killed in October, 2006 (field #'s 2006.10, 2006.12, 2006.13, and 2006.23). It is unknown if any hatchlings were lost. To rectify this situation, HA staff and the Department enclosed the dens with blueberry netting to prevent red-tailed hawks and other birds of prey from gaining access to the snakes. This netting was installed in early November 2006. Unfortunately, this method proved unsuitable for preventing red-tailed hawks from entering the corrals. A red-tailed hawk crashed through the netting into the corral and killed/partially consumed another study snake (field # 2006.27) on November 17, 2006. This hawk was captured by HA's, Michael McGraw and Pete Mooney and taken to the Barnegat Animal Clinic for observation (**Figure 4**). Over the winter, this blueberry netting continually deteriorated from harsh weather conditions (snow, wind, ice) (**Figure 5**). Arrangements were made for sturdier netting to protect the dens. The final predation took place on March 14, 2007, just prior to the commencement of new netting construction. In late March 2007 Walters Homes, Inc. contracted Butterick Bulkheading to install two 30 foot utility poles on opposite sides of each den. With the help of E. Sambol Corporation, support cables were run between the two poles and new netting was installed over the dens (**Figure 6**). This netting is 65lb test, 2 inch mesh that is commonly used in batting cages and game farms. This netting continues to be successful in holding up in adverse weather conditions. No known raptor predation has occurred in the dens after the new netting was installed over the dens.

On October 16, 2007, study snake 2007.13 was killed and partially consumed outside of the den corrals in a forested section of Stafford Forge Wildlife Management Area. Based upon the evidence found at the scene, it is HA's professional opinion that this death was from a natural raptor predation. Red-tailed hawks, along with other Buteonid hawks are known to prey upon a variety of snake species (Fitch and Bare, 1978).

Forest Fire

The forest fire on May 16, 2007 had a major impact on the ongoing northern pine snake study at the SBP site. The forest fire started on the Warren Grove Bombing Range and swept E/NE through the Stafford Forge Wildlife Management Area and the Stafford Business Park site (**Figure 7**). The fire burnt over 17,000 acres of forest in and around Stafford Forge Wildlife Management Area. The fire also severely damaged the snake management fields. All of the three acre outer corrals on Dens 1, 4, and 6 were severely damaged. Vegetative cover inside the three acre enclosures was thoroughly incinerated. The one acre inner corrals faired better, with the exception of Den 1. The inner corral fence around Den 1 was damaged and one corral trap was lost (**Figure 8**). All other inner corral fences faired well, although portions of the landscape cloth were destroyed. The protective netting covering Den 1 was also completely destroyed. The netting over the other dens suffered only minor damage. Immediately following the fire, HA staff began repairing the damages to the corral walls and netting. Landscape cloth was replaced where needed on the inner corral fences around Dens 2 - 6. The entire inner corral fence and netting around Den 1 was replaced.

HA staff and the Department decided against repairing the corral fences surrounding the three acre enclosures of Dens 1, 4, and 6. It was determined that their was not enough vegetative cover left in the three acre enclosures to provide suitable concealment from potential predators. All snakes that were to be confined in the three acre enclosures of Dens 1, 4, and 6 for the 2007 field season were instead confined to the one acre enclosures associated with these dens. HA attached traps to the outer corral fences. This was done in an attempt to re-capture any snakes previously released into the three acre corrals, primarily hatchlings. The traps and outer corral walls were taken down two weeks after the fire.

MATERIALS AND METHODS

SURVEYORS

The following HA staff 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, Brian Scott, Michael Zappalorti and Robert Zappalorti.

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 specific species within a particular study area or ecosystem (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 often result in the best assessment of species abundance and richness. The following visual search methods were preformed:

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 our 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 were 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, furniture were overturned. Open, sunny areas were searched for surface active or basking snakes and lizards. 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 were 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 dead reptiles, amphibians, or other animals, which are killed as they attempt to cross. These "road-killed" animals were identified and provided useful information on migration routes, activity patterns, and habitat utilization/partitioning. The basic presence or absence of a species in a particular area was also determined by the identification of their remains (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 high activity times of the year. Animals moving across roads were easily identified and/or captured.

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 9**). Additionally, pine snake nesting can be documented by locating the new hatchlings or their fresh shed skins in early September, at a time when weathering often makes characteristic sand piles difficult to identify (Zappalorti, pers. obs.).

The primary goal of these surveys was to delineate critical pine snake nesting habitat. In this visual survey technique, 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 2007, most nesting habitat onsite had already been altered so the effort expanded into the surrounding state-owned forest. The management fields created in 2006 are expected to provide some nesting habitat in the future and will be surveyed in the continuing years.

Drift Fence Trapping

One large drift fence (totaling approximately 13,000 feet with 139 box traps) was erected around the study site, traversing various habitat types in an attempt to capture free-ranging pine snakes as well as exclude them from entering the site. The fence was erected with functional traps being attached by April 16, 2007. This technique was used in conjunction with the visual sampling techniques described above to increase the chance of capturing pine snakes. The fence line serves a dual purpose of hindering access to the construction site by small terrestrial animals (reptiles, amphibians, and small mammals) and capturing any animals trying to leave or enter the site. 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 in a trench, 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 measured approximately three (3) feet long, one (1) foot high, and one foot wide. The traps were constructed from treated plywood and three inch 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 (**Figure 10**). Leaves were placed in each trap to provide a cool, moist retreat for trapped animals, and a wooden shade board was placed over the top to reduce exposure to the sun.

***Radio-telemetry Field Method*s**

Radiotracking 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. Potted units 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 were conducted by qualified HA staff members in HA's laboratory in Jackson, New Jersey. Any surgical implantation on study snakes moving forward will be conducted by a qualified HA staff member.

Pine snakes with transmitter implants were located in the field once per 48 hour period using a Wildlife Materials International (Model TRX-1000S) 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.

Radiotelemetry: Activity Range Analysis

Radiotelemetry allowed 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. 1999, 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. Three different measures of activity range were calculated: 90% and 50%. 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 radiotelemetry data.

Onsite Monitoring

Due to the considerable amount of habitat alteration at the Stafford Business Park, an environmental monitor is required to be staffed until project completion. This monitor oversees groundbreaking activities on site that may potentially disrupt, unearth, injure, or kill any state-listed species (plant or animal). This HA staff member was present on-site Monday thru Friday during operation hours throughout the active pine snake season (April - November). Some activities required more intense monitoring than others. These activities include, but were not limited to, forest clearing, stump ripping, stump pile grinding, topsoil stripping, and destruction of existing debris piles. Existing den excavations were monitored very closely by HA staff and Jean Montgomery of the Pinelands Commission (**Figure 11**).

With the assistance of Walters Homes, Inc., a telephone chain-of-command system was organized. This ensured that the environmental monitor is rapidly informed of any reptile or amphibian found/seen by any contractor onsite, prompting capture of the animal. Any animals captured on the property were removed to the adjacent state-owned forest.

RESULTS

DESCRIPTION OF EXISTING CONDITIONS AND HABITATS

The 388 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 (see site map).

The northern portion of the property is within the buffer zone for the Mill Creek wetland corridor. Here, there are a variety of wetland habitats, such as Atlantic white cedar (*Chamaecyparis thyoides*) swamp, deciduous hardwood swamp, and emergent wetland. The ecotonal transition to oak/pine upland forest, and the oak/pine forest, is still partially existing and will remain forested, as a good portion is protected within the wetland buffer. Both initial captures and relocations of pine snakes throughout the 2007 active season have been in this portion of the property.

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 has been cleared and graded to the property line for the ongoing development. The two known, natural hibernacula onsite were located in this portion of the site. Both were excavated under close observation by two HA staff members and Jean Montgomery of the Commission on April 11, 2007. No pine snakes or any other snake species were found.

In the west portion of the site was the disturbed open field. Native grasses, such as switchgrass (*Panicum virgatum*), little blue-stem (*Schizachyrium scoparium*), broomsedge (*Andropogon virginicus*), and Indian grass (*Sorghastrum nutans*), along with non-native and invasive grasses, such as African love grass (*Eragrostis curvula*), and common reed (*Phragmites australis*) made up the majority of this open-canopied area. This area was confirmed as both foraging and nesting habitat for pine snakes prior to development. As part of the site remediation and development, one hundred percent (100%) of the open disturbed field habitat has been altered. It now serves as a capped landfill, storm water basins, Ocean County municipal property, and borrow areas that have been graded and are slated for the residential development portion of the SBP project.

The eastern portion of the site had existing buildings, paved roads, retention ponds, some upland pine forest and unlicensed landfills. It has since been cleared, graded, and prepared for commercial development and new roadways. There is no remaining habitat for pine snakes in this area.

REPTILE AND AMPHIBIAN SURVEYS

Visual Survey Results

A total of 28 reptile and amphibian species were documented in the 2007 active season as a result of the previously mentioned survey techniques in and around the SBP property. These species are:

1. eastern box turtle (*Terrapene c. carolina*)
2. spotted turtle (*Clemmys guttata*)
3. eastern painted turtle (*Chrysemys p. picta*)
4. snapping turtle (*Chelydra serpentina*)
5. northern fence lizard (*Sceloporus undulatus hyacinthinus*)
6. northern water snake (*Nerodia s. sipedon*)
7. redbelly snake (*Storeria o. occipitomaculata*)
8. eastern garter snake (*Thamnophis s. sirtalis*)
9. eastern ribbon snake (*Thamnophis s. sauritus*)
10. southern ringneck snake (*Diadophis p. punctatus*)
11. eastern worm snake (*Carphophis a. amoenus*)
12. rough green snake (*Opheodrys aestivus*)
13. eastern hognose snake (*Heterodon platirhinos*)
14. northern black racer (*Coluber c. constrictor*)
15. northern pine snake (*Pituophis m. melanoleucus*) (state-threatened species)
16. eastern kingsnake (*Lampropeltis g. getula*)
17. coastal plains milk snake (*Lampropeltis triangulum temporalis*)
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*)
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*)

It should be noted that eastern hognose snake, northern black racer, rough green snake, northern fence lizard, eastern box turtle and Fowler's toad were the most often observed species while HA was conducting visual surveys.

Drift Fence Survey Results

Drift fence surveys began on April 16, 2007. 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 139 traps along approximately 13,000 feet of drift fence. However, on May 16, 2007 the forest fire destroyed a large portion of the perimeter drift fence along with 115 traps (**Figure 12**). As a result, drift fence surveys did not begin again until June 13, 2007 (**Figure 13**). After reconstruction of the drift fence line 134 traps were attached (**Figure 14**). Closing of the traps for the winter season began on November 1 and concluded on November 11, 2007. Any open traps were checked every 48 hours until all were closed.

The purpose of the perimeter drift fence was to prevent animals (specifically pine snakes) from entering the construction site and to capture any snakes trying to leave the site. During the course of the season, 24 species of reptiles and amphibians, 9 species of mammals, and one species of bird were found captured in the drift fence traps. Eastern hognose snake, northern black racer, Fowler's toad, red-backed salamander, and green frog were the most commonly captured reptile and amphibian species. In 2007, five individual pine snakes were captured in the traps on six different occasions. Of the five, four were adults and one was a juvenile. Only one of the captured pine snakes was a new capture. This snake was captured on August 17, 2007. It was PIT tagged and fitted with an external transmitter to enable HA to radio track it to a natural hibernaculum. One gray tree frog *(Hyla* sp.) was captured in a drift fence trap during the season. White-footed mice (*Peromyscus leucopus*) were the most frequently captured mammal species and ovenbird (*Seiurus aurocapillus*) was the only bird species captured in a trap.

Radio-tracking

In accordance with northern pine snake relocation and management plan, and radio-tracking and monitoring plan for Stafford Business Park and Stafford Forge WMA (Zappalorti and Golden, 2006), HA commenced the seven year radio-tracking study in 2007. Through random opportunistic survey techniques HA staff were able to capture 16 non-relocated pine snakes, 8 males and 8 females, to include in the study as stipulated in the aforementioned radio-tracking plan. A total of thirty-four adult pine snakes were radio-tracked by HA staff members during the 2007 season. Of these thirty-four snakes, twelve were radio-tracked inside of the two winter treatments and 22 were tracked in and around Stafford Forge Wildlife Management Area. Please refer to the following individual snake synopsis for specific information on each individual pine snake radio-tracked during the 2007 field season.

Individual Snake Synopsis and Kernal Home Range Analysis Maps

A brief synopsis of every adult pine snake involved in the radiotelemetry aspect of this project, currently alive or deceased is detailed below. Any trap captures mentioned in this section may be supported by the GIS map **Figure 14**. Dave Golden, senior zoologist, of the Department has provided home range analysis maps of snakes radiotracked outside of the corralled dens in the 2007 active season. These maps are within the synopsis for each snake. Please refer to the maps for information on each individual pine snake's activity range during the season.

N. Pine Snake No. 2006.06 **(♂)** 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 Den 6, a two winter treatment, on 09/22/06. This snake was killed by a red-tailed hawk on 03/14/07.

N. Pine Snake No.2006.07 **(♂)** 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 in the small intestine of the snake and this was determined to be the cause of death.

N. Pine Snake No. 2006.08 **(♀)** was 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 Den 6, a two winter treatment, on 04/03/07. On 05/01/07 it was caught in a corral trap egressing from the den 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 lack of cover within the three acre corrals after the fire increased the possibility of predation on the snakes, especially by raptors. This snake was captured and re-released into the one acre enclosure of Den 6. On 09/07/07, HA staff found this snake's transmitter to be moving freely within the body cavity. It was removed from the den and taken to HA's lab where it is being held over the 2007-2008 winter.

N. Pine Snake No. 2006.09 **(♀)** was relocated 94 times during the 2007 field season. It was originally captured during a presence or absence survey conducted by EcolSciences, Inc. in 2004. It was recaptured by EcolSciences, Inc. on 05/09/06, implanted with an internal transmitter, and re-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 to hatch out. This snake was released in Den 2, a one winter treatment, on 09/22/06 and hibernated there. The snake egressed from the den on 04/25/07.

For the majority of the 2007 field season this snake never traveled far from the management fields, except in early August and late fall when it crossed Mill Creek into an upland oak/pine forest approximately 1.1 kilometers N/NE of the management fields where it eventually hibernated. It was often relocated in an upland pine forest between management field 3 and Hay Road, or between Hay Road and Mill Creek. Many relocations were within a few meters of the road. This snake also spent several relocations in a row, on four different occasions during the field season, inside the man-made earth berm separating management field 3 from the forest. On one occasion it was observed opaque while basking on top of the berm, implying that it may have been using the berm as a potential shedding station.

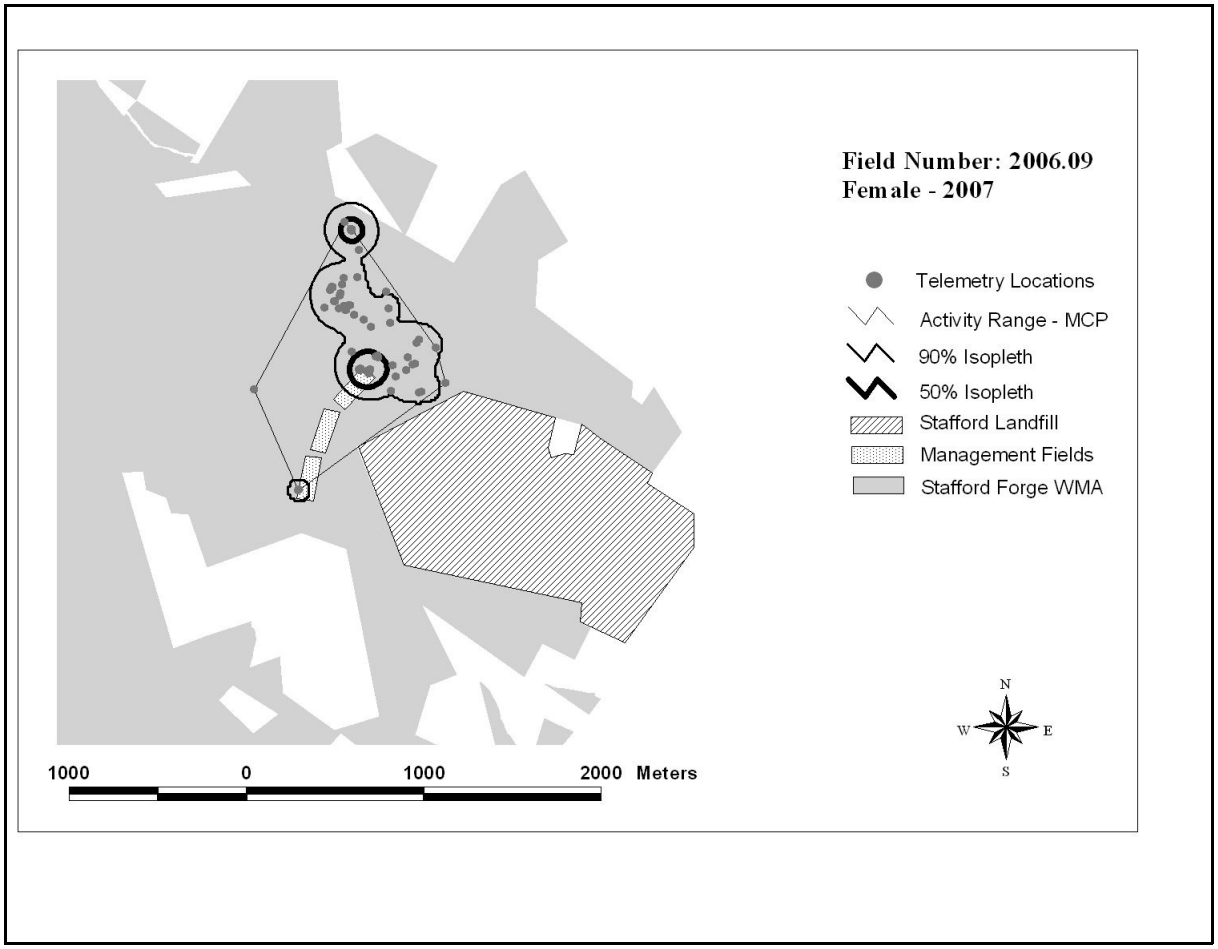


Figure 15. Radiotelemetry locations and activity range (minimum convex polygon and 50% and 90% isopleth from kernal analysis) for pine snake # 2006.09. The area used while being radiotracked in 2007 is 209.70 acres (84.9 hectares).

N. Pine Snake No. 2006.10 **(♂)** was originally captured by EcolSciences, Inc. on 05/09/06 near the landfill. This snake was released into Den 6, a two winter treatment, on 09/22/06. 0n 10/30/06 HA staff observed two red-tailed hawks flush from the pine/oak island inside the corral. Upon entering the den corral, the snake's carcass was found partially consumed. It is HA's belief that these two hawks were feeding on the pine snake. They both flushed, perched in nearby trees, and began cleaning their beaks on tree branches (a 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. 2006.11 **(♂)** was relocated a total of 89 times during the 2007 field season. It was caught by EcolSciences, Inc. on the landfill access road on 05/17/06. It was released into Den 3, a one winter treatment, on 09/22/07. This snake was caught in a corral trap attempting to egress from the den on 05/01/07 and was released into the surrounding forest. It was often relocated in a charred upland pine forest SW of the site. A few relocations occurred along the perimeter drift fence on the south side of the site. On 08/17/07 it was relocated on the landfill in the same area that 2006.26 had been previously relocated. It was collected from the site and relocated inside a man-made earth berm that separates management field 3 from the forest. This snake hibernated approximately 75 meters SE of management field 3 in an underground burrow in an upland pine forest. Snake field number 2006.26 is also denning in this burrow.

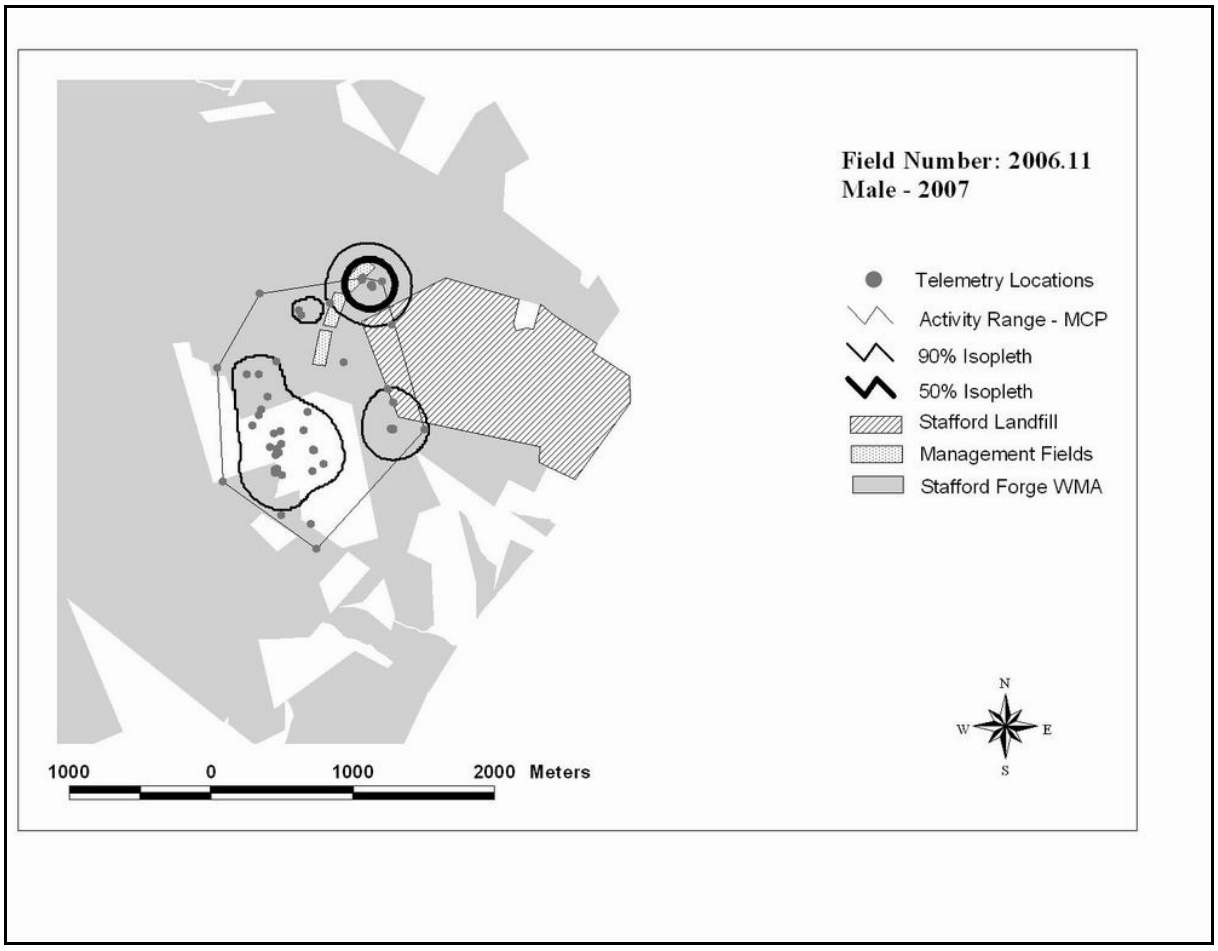


Figure 16. Radiotelemetry locations and activity range (minimum convex polygon and 50% and 90% isopleth from kernal analysis) for pine snake # 2006.11. The area used while being radiotracked in 2007 is 485.15 acres (196.34 hectares).

N. Pine Snake No. 2006.12 **(♂)** 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. Two red-tailed hawks were flushed from nearby prior to the discovery of the snake's carcass.

N. Pine Snake No. 2006.13 **(♂)** 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. 2006.15 **(♂)** was captured in trap 24 along the perimeter drift fence by EcolSciences, Inc. on 05/17/06. This snake overwintered in HA's lab and was released into Den 4, a two winter treatment, on 04/03/07. This snake's transmitter did not function all season long. The snake was caught outside of the hibernaculum on 06/23/07 and held in the HA office. It was decided not to remove the transmitter and the animal was released back into Den 4 on 11/09/07.

N. Pine Snake No. 2006.16 **(♂)** was originally captured by EcolSciences, Inc. in trap 27 along the perimeter drift fence on 05/18/06. This snake overwintered in the HA lab, due to poor health, and was released into Den 1, a two winter treatment, on 04/03/07. This snake was not relocated outside of the hibernaculum until 06/11/07 when it was captured in the den's west trap attempting to egress. Because of minimal canopy cover resulting from the forest fire, the snake was confined to the one acre corral for the entirety of the field season. It is hibernating inside the Den 1 hibernaculum for the 2007-2008 winter.

N. Pine Snake No. 2006.17 **(♂)** 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 Den 6, a two-winter treatment on 04/03/07. This snake was radio-tracked inside of the one acre corral of Den 6 throughout the entire season. It was not observed outside of the hibernaculum until 06/27/07. The majority of the time this snake was found to be concealed inside the hibernaculum. It is hibernating there for the 2007-2008 winter.

N. Pine Snake No. 2006.18 **(♂)** was captured on the landfill slope by EcolSciences, Inc. on 05/22/06. This snake was released into Den 3, a one winter treatment, on 09/22/06 and hibernated there. This snake was caught in a corral trap egressing from the den on 05/01/07 and was released. The snakes 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. The snake's charred corpse was found in the same area on 05/17/07 following the forest fire.

N. Pine Snake No. 2006.19 **(♀)** was captured by EcolSciences, Inc. on 05/24/06 on the NW corner of the firing range. This snake laid eggs in the field which were subsequently predated. It overwintered in HA's lab for the 2006-2007 winter season due to exaggerated breathing behavior and a migrating transmitter. This snake's transmitter was removed in September of 2006 for health reasons and released into Den 1 (two winter treatment) on 04/03/07. This snake was observed by HA staff in Den 1 on 09/10/07 and was in good health.

N. Pine Snake No. 2006.20 **(♂)** was 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 Den 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 Den 4 and had suffered some slight burn trauma to its face. (**Figure 17**) On 05/20/07 this snake was recaptured and released back into the one acre enclosure in Den 4. It was radio-tracked for the remainder of the season inside the one acre enclosure and overwintered in the artificial hibernaculum.

N. Pine Snake No. 2006.21 **(♀)** was relocated 90 times during the 2007 field season. It was originally captured in trap 95 along the perimeter drift fence by EcolSciences, Inc. on 05/27/06. This snake was released into Den 2, a one winter treatment, on 09/22/06 and hibernated there. This snake was tracked inside of Den 2 until 05/03/07 when it was captured in a corral trap attempting to egress from the den. Until 06/21/07 this snake was consistently relocated in the interior of the burnt upland pine forest W/NW of the management fields. On 06/23/07 this snake made a large move. It was located crossing the wetland corridor of Mill Creek over 1.6 kilometers N/NW of the management fields. By late July this snake was relocated as far as 2.8 kilometers N/NW of the management fields in an upland oak/pine forest on privately owned property between Mill Creek and Route 72 (See home range analysis for further details). Several times it was relocated within 20 meters of Route 72 and on one occasion was removed from the shoulder of Route 72 by HA staff. This snake

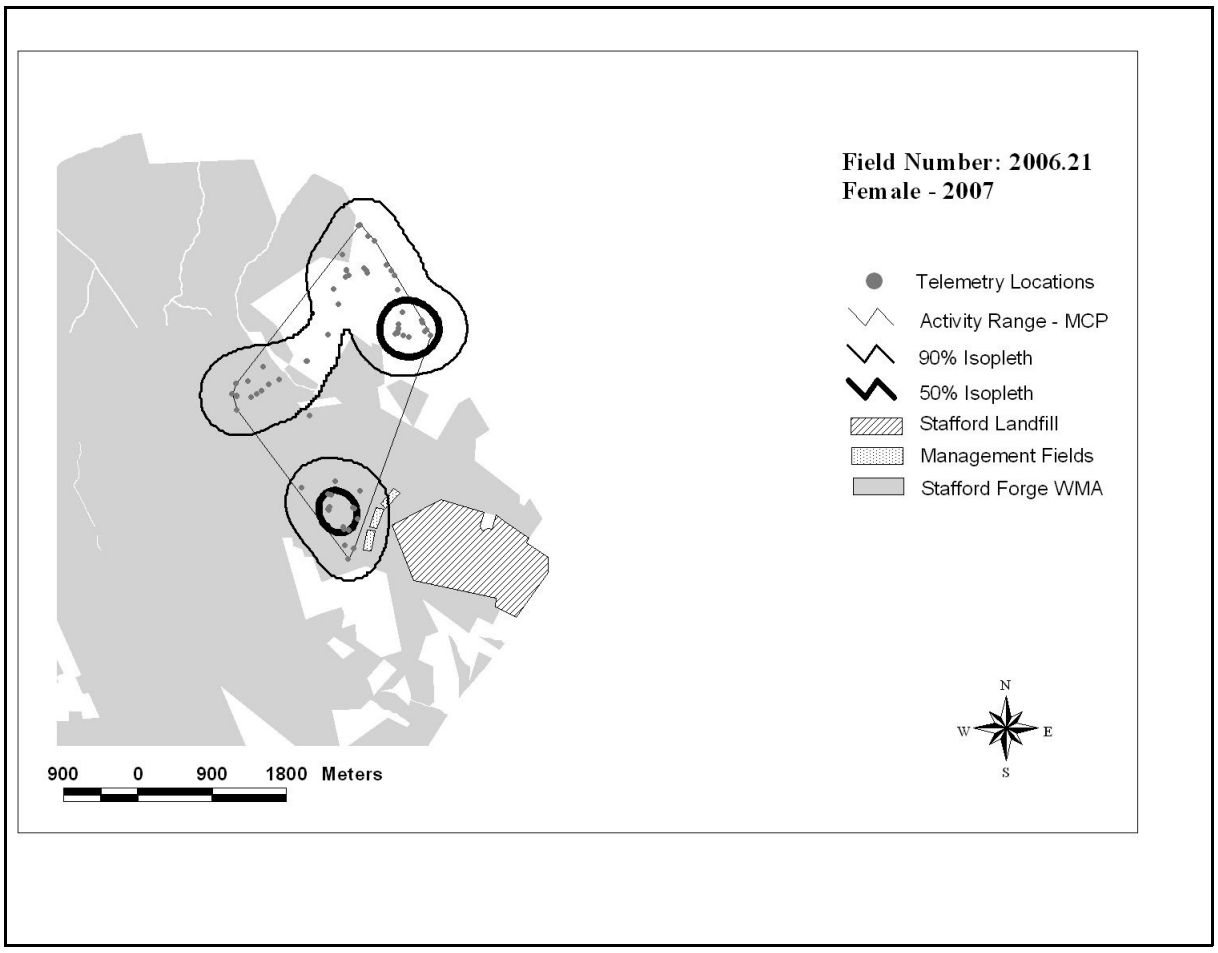


Figure 18. Radiotelemetry locations and activity range (minimum convex polygon and 50% and 90% isopleth from kernal analysis) for pine snake # 2006.21. The area used while being radiotracked in 2007 is 1236.85 acres (500.54 hectares).

hibernated in an upland oak/pine forest on privately owned land approximately 2.4 kilometers north of the management fields.

N. Pine Snake No. 2006.22 (♂) was originally captured by EcolSciences, Inc. in trap 95 along the perimeter drift fence on 05/27/06. This snake was released into Den 1, a two winter treatment, on 09/22/06. On 04/24/07 this snake was found in the west trap of Den 1 attempting to leave the inner corral and was released into the three acre outer corral. On 05/17/07, the day after the forest fire, this animal was radio-tracked and 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 inner corral of Den 2 until repairs could be made on Den 1. On 06/15/07 this snake was again released into the one acre enclosure of Den 1 were it was radio-tracked throughout the season. This snake hibernated inside the Den 1 hibernaculum for the 2007-2008 winter.

N. Pine Snake No. 2006.23 (♀) was originally captured by EcolSciences, Inc. on 5/30/06 in trap 74 along the perimeter drift fence. The snake was released into Den 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. A red-tailed hawk was seen screaming from a nearby tree.

N. Pine Snake No. 2006.26 (♂) was relocated 78 times during the 2007 field season. It was captured by EcolSciences, Inc. during the summer of 2006. It was released into Den 2, a one winter treatment, on 09/22/06. This snake was caught in a corral trap on 05/01/07 attempting to egress from the den and was released. This snake spent the entire season within 0.75 kilometers of the management fields. This snake was relocated at three different locations on the landfill site during the season. When this occurred the animal was radio-tracked underground several times a day, every day, until it was found on the surface and could be removed from the construction area. The snake may have gained access to the landfill via the management field's access road. It was also relocated inside perimeter drift fence traps, outer den corral traps, and along the drift fence itself. On three different occasions the snake was relocated several times in a row concealed in the man-made earthen berms along management field 3. The last such occurrence found the animal concealed in one berm for over a month, from 08/25/07 to 10/02/07. The snake was also relocated in or near the berms on a single relocation basis throughout the season. This snake hibernated, for the 2007-2008 winter, with 2006.11 in charred upland pine forest approximately 75 meters SE of the management fields.

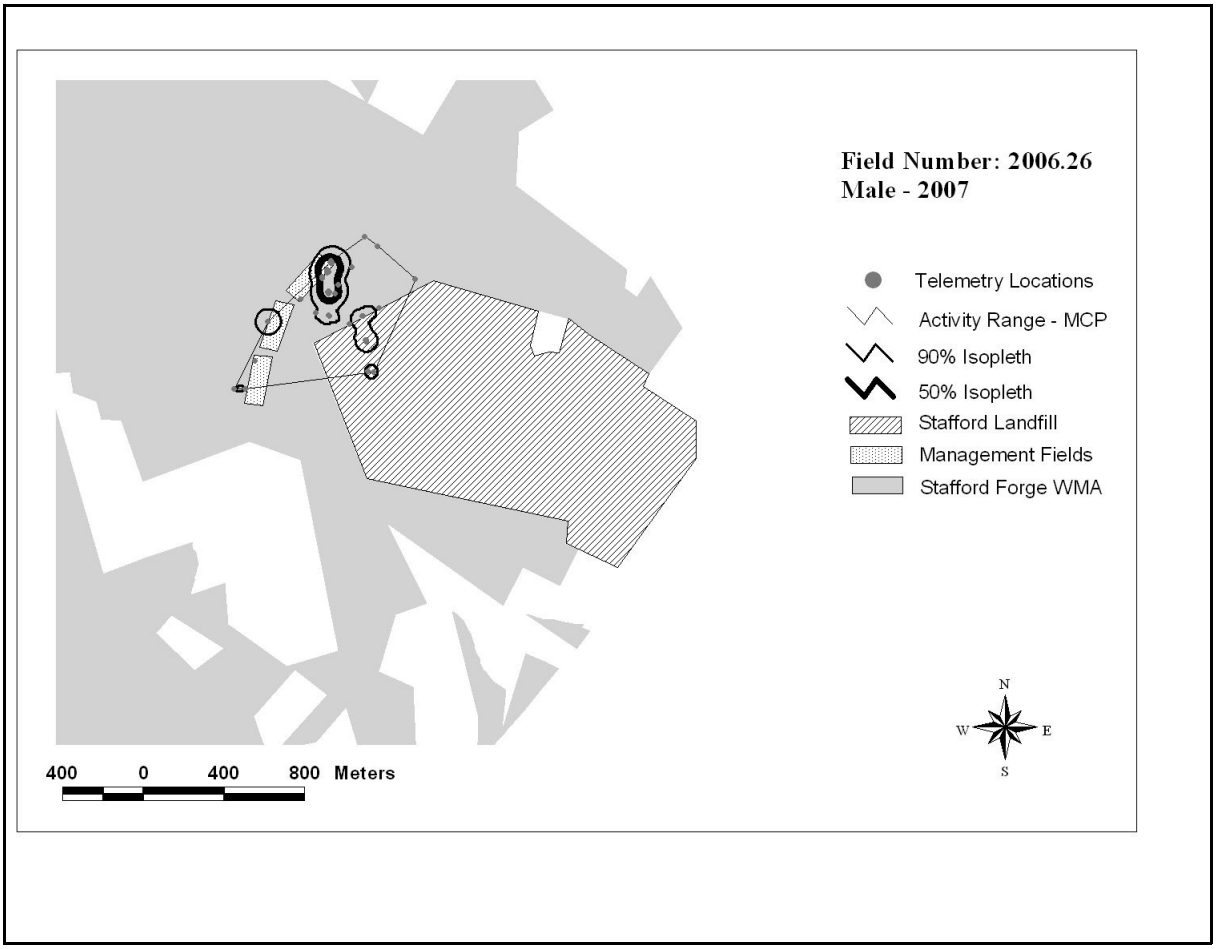


Figure 19. Radiotelemetry locations and activity range (minimum convex polygon and 50% and 90% isopleth from kernal analysis) for pine snake # 2006.26. The area used while being radiotracked in 2007 is 91.16 acres (36.89 hectares).

N. Pine Snake No. 2006.27 (♀) 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 Den 1 on 09/22/06. On 11/17/06 HA staff observed a red-tailed hawk trapped between the ground and the netting surrounding Den 1. Once the hawk was removed from the den HA staff discovered the partially consumed carcass of this snake on the SE side of the hibernaculum.

N. Pine Snake No. 2006.28 (♀) was originally captured by HA on the landfill on 06/23/06. This snake overwintered, for the 2006-2007 winter, in the HA lab and was released into Den 1, a two winter treatment, on 04/03/07. This snake was captured in the west corral trap on 04/20/07 attempting to leave the den and released 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 corral. On 05/17/07, the day after the fire, this snake was observed leaving the berm and was relocated into Den 2 due to fire damage to Den 1. On 06/17/07 it was captured in a Den 2 corral trap and moved back into Den 1. For the remainder of the field season it was radio-tracked inside of the one acre corral of Den 1 and hibernated in the hibernaculum.

N. Pine Snake No. 2006.29 (♀) was captured on 06/26/06 in trap 97 of the perimeter drift fence by EcolSciences, Inc. This snake was gravid and laid 10 eggs in the HA lab. It was released into Den 6, a two winter treatment, on 09/22/06. 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 in a charred upland pine forest behind the management fields. The snake had escaped the corral enclosure during the fire, even though the corral fence had managed to stay intact minus the felt covering. The snake was recaptured on 05/20/07 when found basking in a charred upland pine forest and released back into the one acre enclosure of Den 6. The animal was radio-tracked inside the one acre corral throughout the remainder of the season and is hibernating in Den 6 for the 2007-2008 winter.

N. Pine Snake No. 2006.30 (♀) 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. This snake overwintered in HA's 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. HA will search for this animal upon spring egression and remove the failed transmitter upon re-capture.

N. Pine Snake No. 2006.31 (♀) 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 HA's lab. It overwintered in HA's lab for the 2006-2007 winter and was released into Den 4, a two winter treatment, on 04/03/07. On 05/01/07 this snake was found in the east corral trap of Den 4 and released into the three acre outer corral. From 05/02/07 until 05/14/07 this snake was relocated, all but one time, inside a man made earth berm on the SW side of the three acre corral. For almost a month after the forest fire on 05/16/07 this snake was consistently relocated inside the mound. The decision was made to dig up the snake to determine whether it was deceased. On 06/14/07 the charred remains of this animal and the transmitter were dug out of the earth berm. The forest fire was determined to be the cause of death.

N. Pine Snake No. 2006.32 (♀) was relocated 81 times during the 2007 field season. It was caught in trap 61 along the perimeter drift fence on 07/08/06. The snake was implanted with a transmitter and eventually released into Den 3, a one winter treatment, on 09/22/06. Although the one winter treatments were opened in mid April this snake did not leave Den 3 until 07/05/07, almost two and a half months afterwards. During that time the animal was radio-tracked inside the den and was often relocated inside the hibernaculum. When this snake was relocated on 07/07/07 it was in heavily burnt upland pine forest over 1.5 kilometers west of the management fields in the interior of Stafford Forge Wildlife Management Area. 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.

For the remainder of the season this snake was relocated in this same general area. It was relocated in both burnt and unburnt portions of the forest on the north and south sides of Hay Road. This snake hibernated in a stump hole approximately 30 meters south of Hay Road and approximately 1.8 kilometers N/NW of the management fields in Stafford Forge Wildlife Management Area.

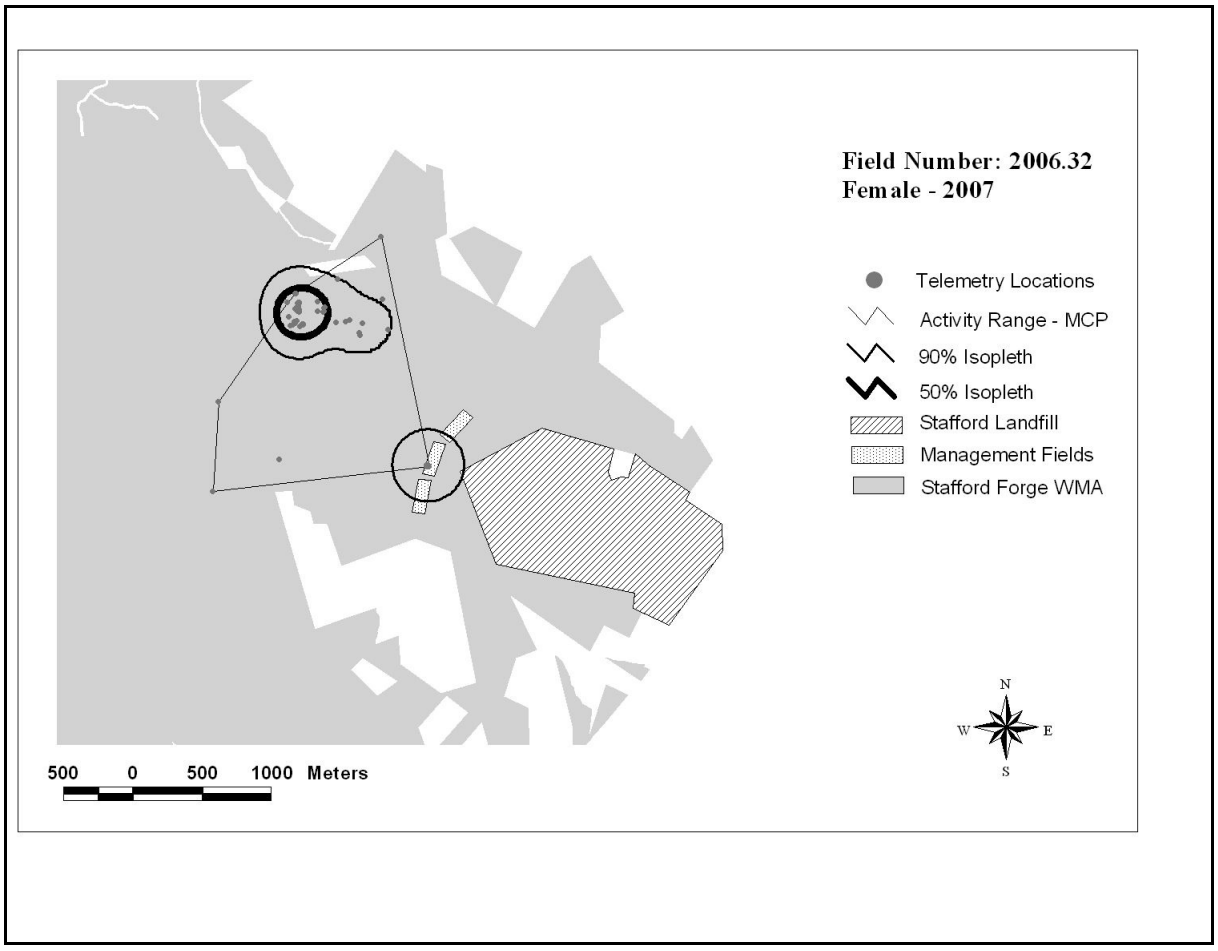


Figure 20. Radiotelemetry locations and activity range (minimum convex polygon and 50% and 90% isopleth from kernal analysis) for pine snake # 2006.32. The area used while being radiotracked in 2007 is 2007 is 447.33 acres (181.03 hectares).

N. Pine Snake No. 2006.33 (♀) was relocated 87 times during the 2007 field season. It was originally captured in trap 5 along the perimeter drift fence by EcolSciences, Inc. on 08/11/06. The animal was implanted with a transmitter and released into Den 5, a one winter treatment, on 09/22/06. 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 Road, a well used dirt road in the interior of Stafford Forge Wildlife Management Area. For the rest of the field season this snake was relocated in the heavily burnt upland pine forest west of the management fields. Often times the snake was within 50 meters of Grays Road. Two times during the season this animal spent a long period of time, up to three weeks on one occasion, concealed in or near a large metal/sand debris pile along the edge of Grays Road. A shed of this snake was located outside of the debris pile after it had spent several relocations there and it is quite probable it was using the pile as a shedding station. This snake hibernated in a large mammal burrow in a heavily burnt portion of the upland pine forest approximately 1.6 kilometers west of the management fields in Stafford Forge Wildlife Management Area.

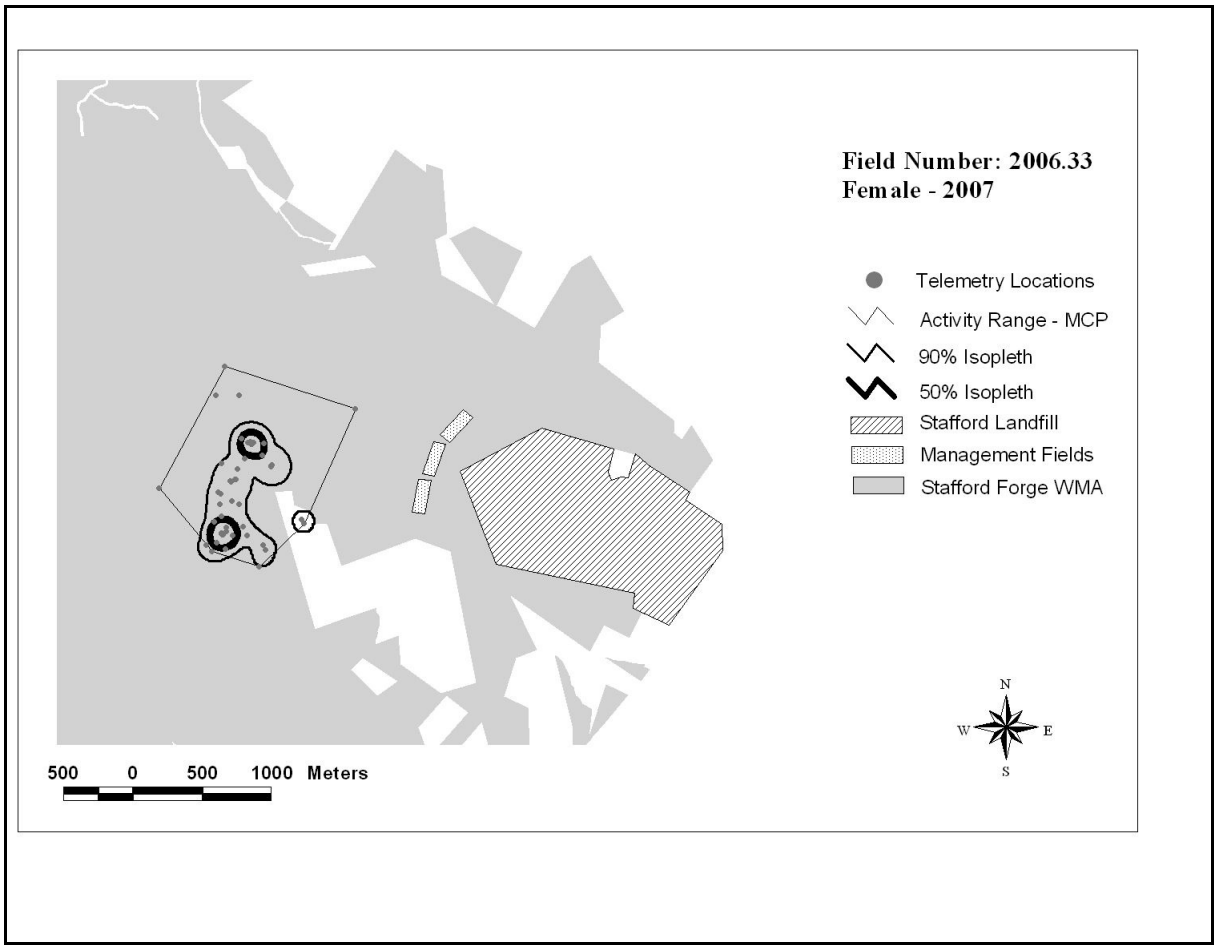


Figure 21. Radiotelemetry locations and activity range (minimum convex polygon and 50% and 90% isopleth from kernal analysis) for pine snake # 2006.33. The area used while being radiotracked in 2007 is 302.48 acres (122.41 hectares).

N. Pine Snake No. 2006.34 (♂) was relocated 89 times during the 2007 fields season. It was caught in trap 85 of the perimeter drift fence by EcolSciences, Inc. on 08/31/06. This snake overwintered in Den 2, a on e winter treatment. This snake was caught in a corral trap trying 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 first few relocations found this snake in the upland pine forest west of the management fields.

By the middle of May the snake had moved south of the site into an upland oak/pine forest. For the majority of the season this snake was relocated inside of a .50 kilometer radius of upland oak/pine forest south of the site. (See home range analysis for more details). Several times it was relocated inside or near a large glass dump pile were other study animals were either captured or trapped during the season. This snake along with 2007.14 used a shingle pile adjacent to the glass dump when pre-shed. This snake hibernated in an upland oak/pine forest approximately 1.3 kilometers S/SW of the redevelopment site.

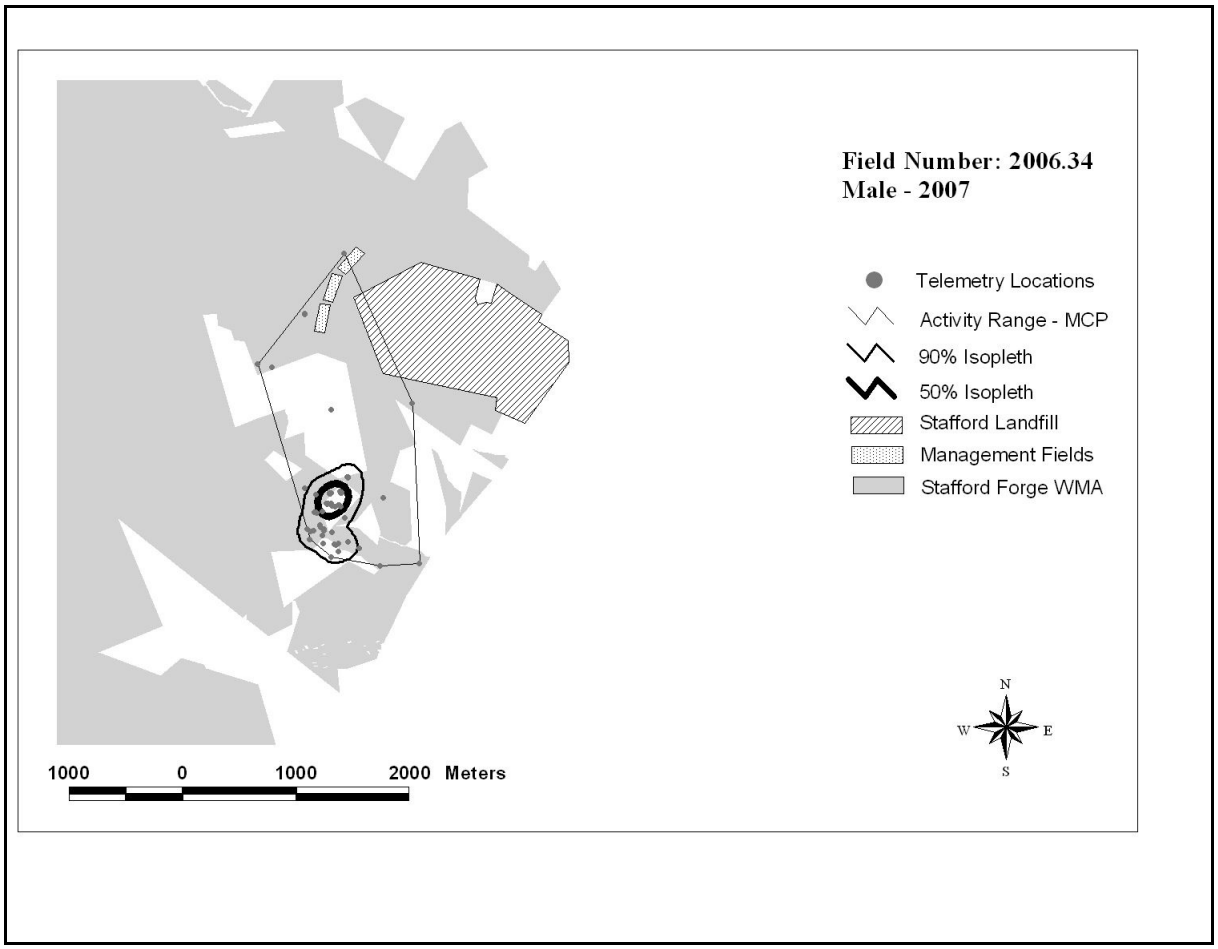


Figure 22. Radiotelemetry locations and activity range (minimum convex polygon and 50% and 90% isopleth from kernal analysis) for pine snake # 2006.34. The area used while being radiotracked in 2007 is 622.58 acres (251.95 hectares).

N. Pine Snake No. 2007.02 (♂) was originally captured by HA staff on 05/02/07. The snake was caught at the base of a stump pile in management field 2. It was implanted with a transmitter and released on 05/04/07. After it's 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. After the forest fire on 05/16/07 the remains of this snake were found under a burnt pine log in the same location as the animal's last radio-tracked position before the fire.

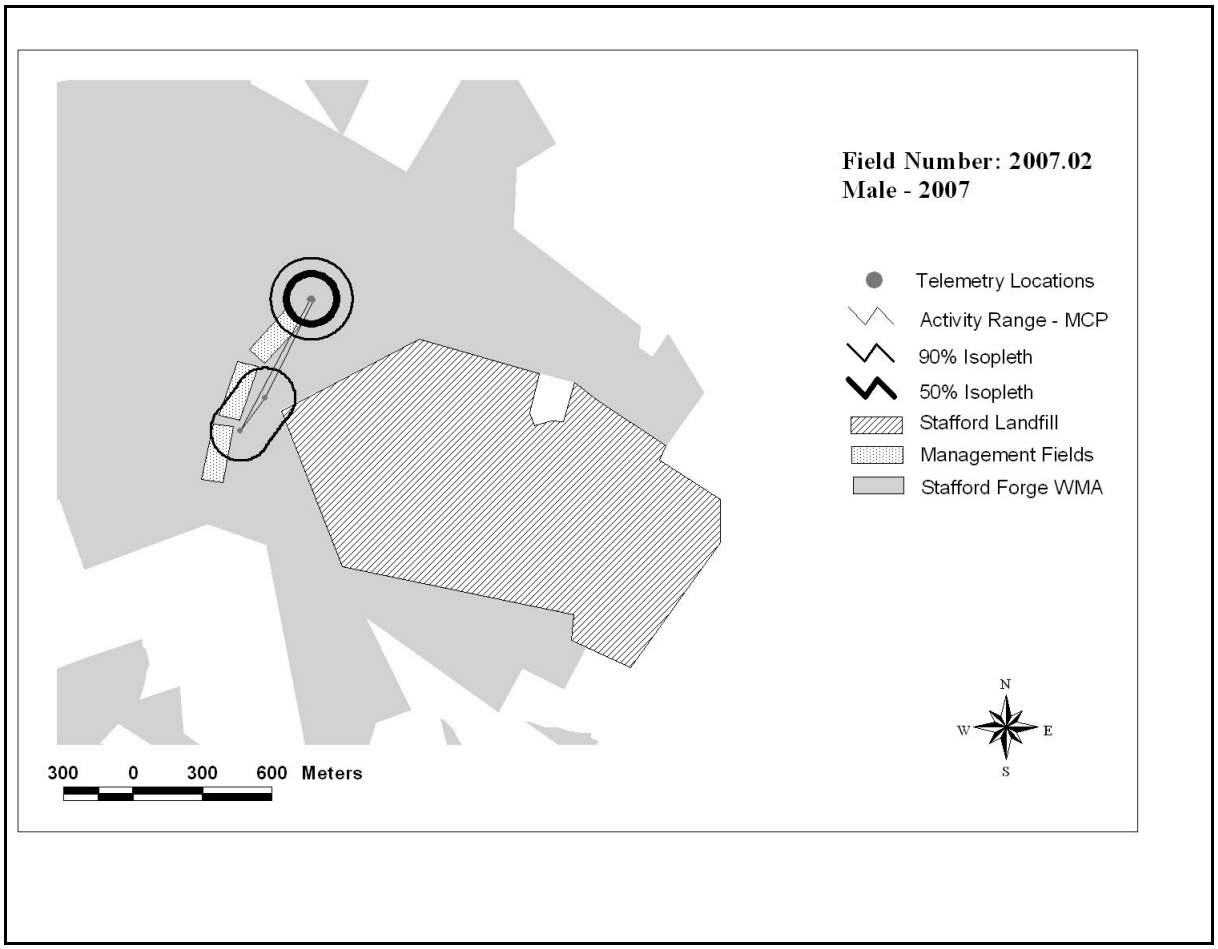


Figure 23. Radiotelemetry locations and activity range (minimum convex polygon and 50% and 90% isopleth from kernal analysis) for pine snake # 2007.02. The area used while being radiotracked in 2007 is 3.07 acres (1.24 hectares).

N. Pine Snake No. 2007.03 (♂) was relocated 77 times during the 2007 field season. It was originally captured by HA staff on 05/24/07 in a heavily burnt area of the upland pine forest west of the management fields. This animal was captured during a random search effort. This snake was implanted with a transmitter and released by HA staff on 05/31/07. Throughout the field season this snake never traveled far from its original capture location. It was often relocated in the burnt pine forest W/NW of the management fields, sometimes within a few meters of Hay Road. This snake also utilized the man-made earth berm along management field 3, spending the first half of August concealed inside the berm on the south side of the field. This snake was also relocated several times in the debris mounds created when clearing the outer corral path for Den 6. This snake hibernated in a large mammal burrow in the upland pine forest 35 meters north of Den 6.

Figure 24. Radiotelemetry locations and activity range (minimum convex polygon and 50% and 90% isopleth from kernal analysis) for pine snake # 2007.03. The area used while being radiotracked in 2007 is 168.72 acres (68.28 hectares).

N. Pine Snake No. 2007.04 (♀) was relocated 56 times during the 2007 field season. It was originally captured by HA staff on 05/25/07 while conducting a random search effort. The animal was captured in an island of disturbed pine/oak forest on the east side of the Stafford Park construction site. It was gravid and held in Den 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, crossing Mill Creek into an upland oak/pine forest on privately owned land. The forest was adjacent to the Manahawkin Nursing and Rehabilitation Center. Several times this snake was relocated within a couple meters of human development. Most notably, the Manahawkin Nursing and Rehabilitation Center's residence facility on the west side of Route 72 and the parking lot for a medical facility also on the west side of Route 72. 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 a mammal burrow at the base of a thicket of mountain laurel only 15 meters from Route 72 on privately owned land.

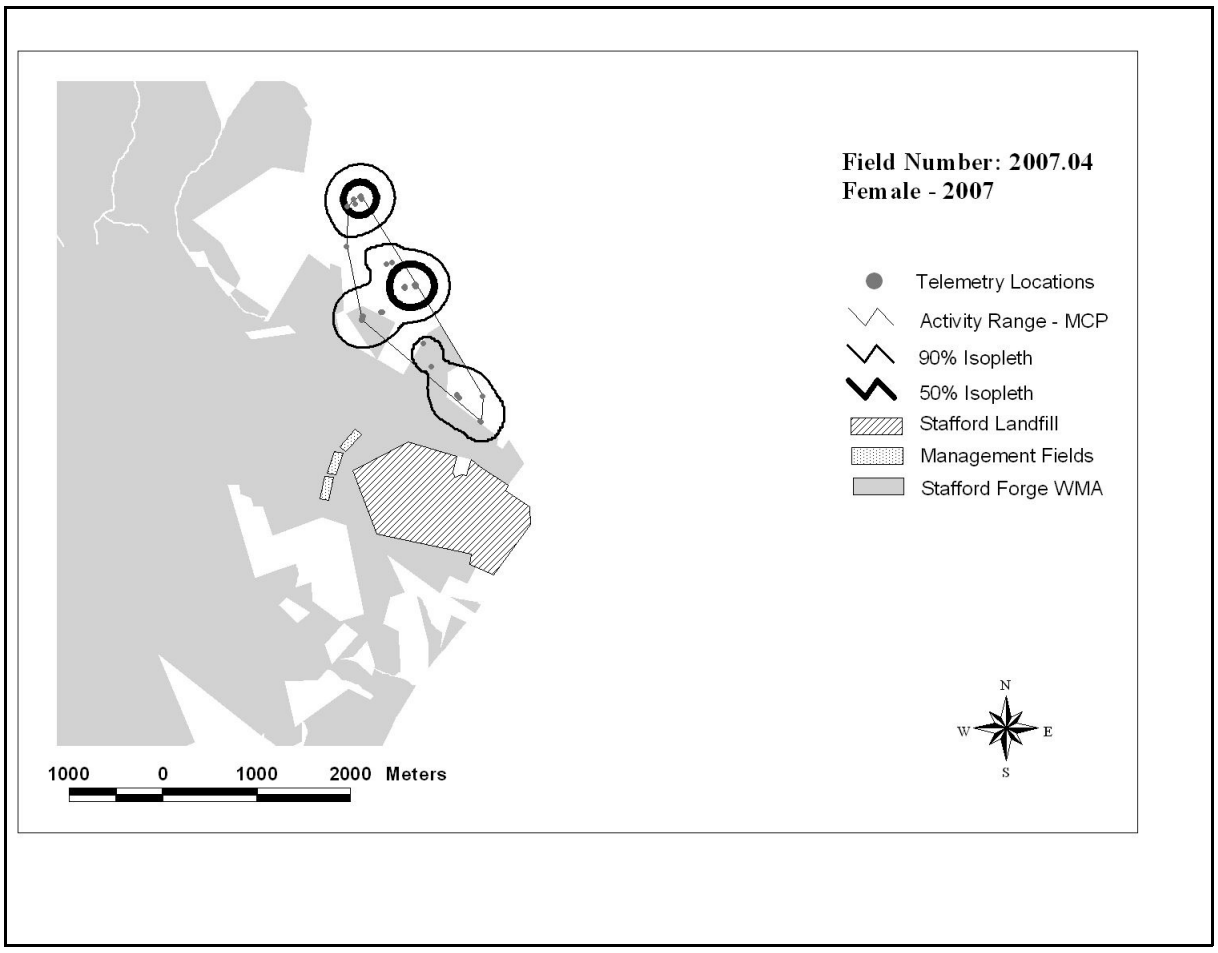


Figure 25. Radiotelemetry locations and activity range (minimum convex polygon and 50% and 90% isopleth from kernal analysis) for pine snake 2007.04. The area used while being radiotracked in 2007 is 291.39 acres (117.90 hectares).

N Pine Snake 2007.05 (♀) was relocated 53 times during the 2007 field season. It was captured by HA staff on 05/28/07. It was observed emerging its head out of a stump hole next to pine snake 2006.34's location south of the construction site. This snake was gravid and released into Den 4 until egg deposition. It was implanted with a transmitter on 07/17/07 and released. Throughout the season this snake never moved any considerable distance from its original capture location. (See home range analysis for further detail) Almost all relocations occurred in an oak/pine or pine/oak forest on privately owned land south of the construction site. This snake hibernated in what is probably a side chamber off of a stump hole in an oak/pine forest on privately owned land.

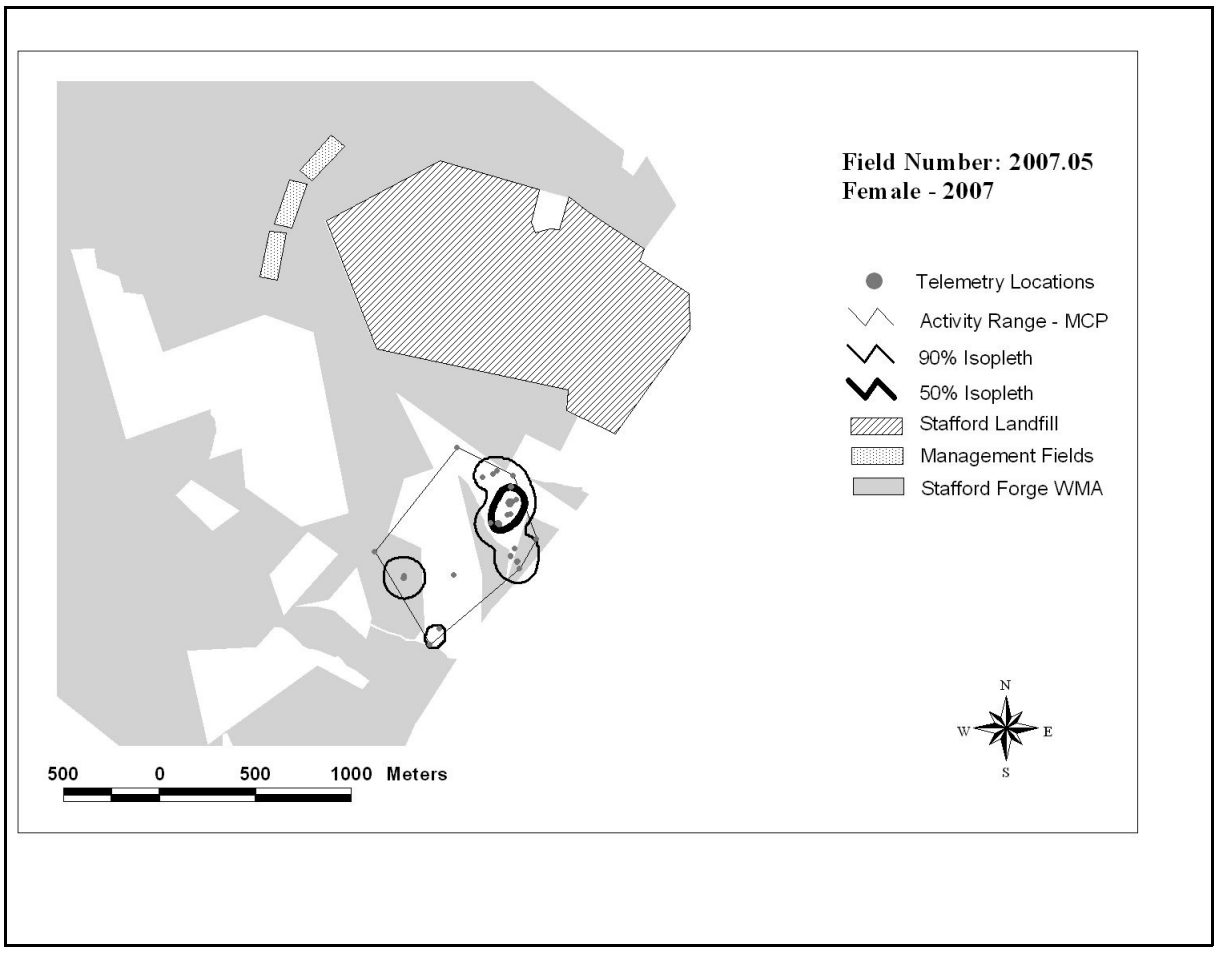


Figure 26. Radiotelemetry locations and activity range (minimum convex polygon and 50% and 90% isopleth from kernal analysis) for pine snake # 2007.05. The area used while being radiotracked in 2007 is 120.92 acres (48.94 hectares).

N. Pine Snake No. 2007.06 (♀) was relocated 18 times during the 2007 field season. It was found by HA staff while radio-tracking. This snake was found traveling in burnt upland pine forest 15 meters from 2006.21's location on 06/03/07. Due to the size of this snake it was decided that a smaller transmitter would be needed for implantation. The snake was placed in Den 1 while waiting for the delivery of the smaller transmitter. This snake was not found up in Den 1 until late in the season. By that time HA determined it was to late in the season to implant a transmitter in the snake. However, 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 were it was released and was only relocated in 3 different locations over the next month. All relocations occurred in the burnt 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.

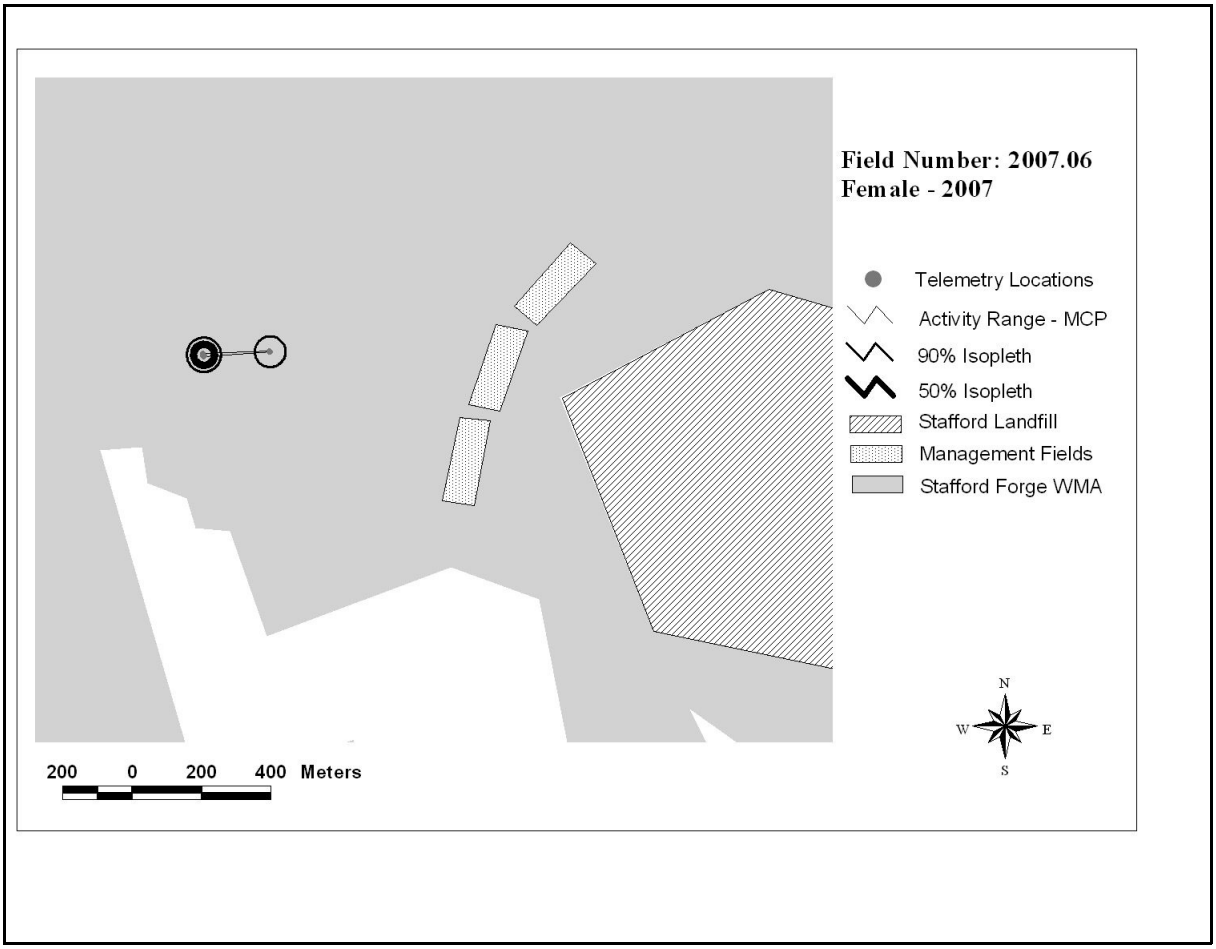


Figure 27. Radiotelemetry locations and activity range (minimum convex polygon and 50% and 90% isopleth from kernal analysis) for pine snake # 2007.06. The area used while being radiotracked in 2007 is 0.27 acres (0.11 hectare).

N. Pine Snake No. 2007.07 (♀) was relocated 54 times during the 2007 field season. It was originally captured on 06/03/07 by HA staff while radio tracking. The snake was observed crossing Hay Road. The snake was gravid and held in Den 6 until egg deposition. It was implanted with a transmitter on 07/17/07 and released the following day. This snake never traveled a considerable distance from were it was captured. It was often relocated along the edge, or within several meters of Hay Road. This snake utilized a variety of habitats throughout the field season, including unburnt and heavily burnt forest, wetland edges, and cedar swamps. It hibernated within Stafford Forge Wildlife Management Area in a large mammal burrow in a heavily burnt pine forest a quarter of a mile from where it was captured.

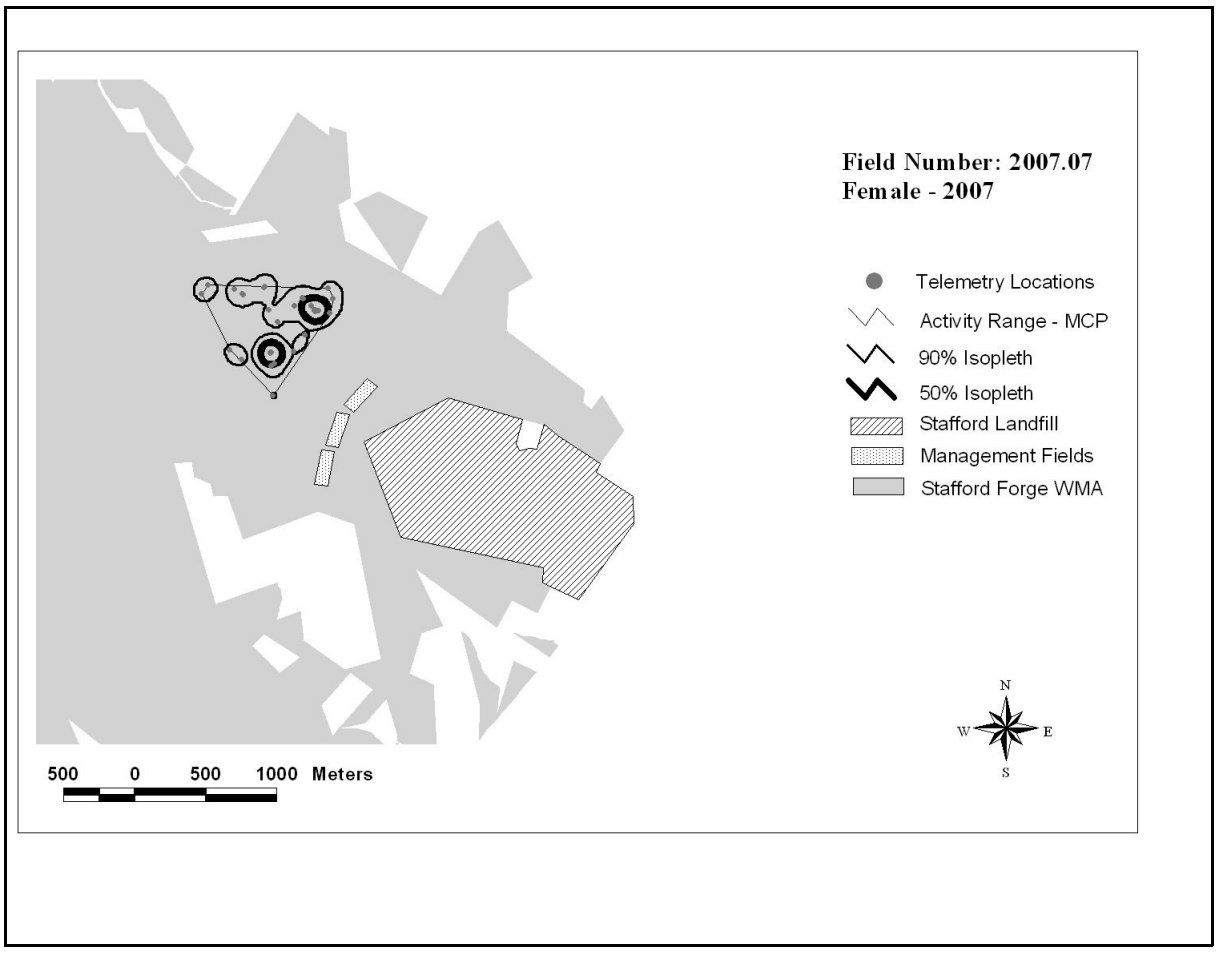


Figure 28. Radiotelemetry locations and activity range (minimum convex polygon and 50% and 90% isopleth from kernal analysis) for pine snake # 2007.07. The area used while being radiotracked in 2007 is 104.48 acres (42.28 hectares).

N. Pine Snake No. 2007.08 (♂) was relocated 22 times during the 2007 field season. It was originally captured by HA staff in a heavily burnt pine forest 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. From 08/03/07 until 09/04/07 this snake was always relocated in either open field or disturbed habitat, including the front lawn of a residence, on private property. All of the property was situated along the west 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.

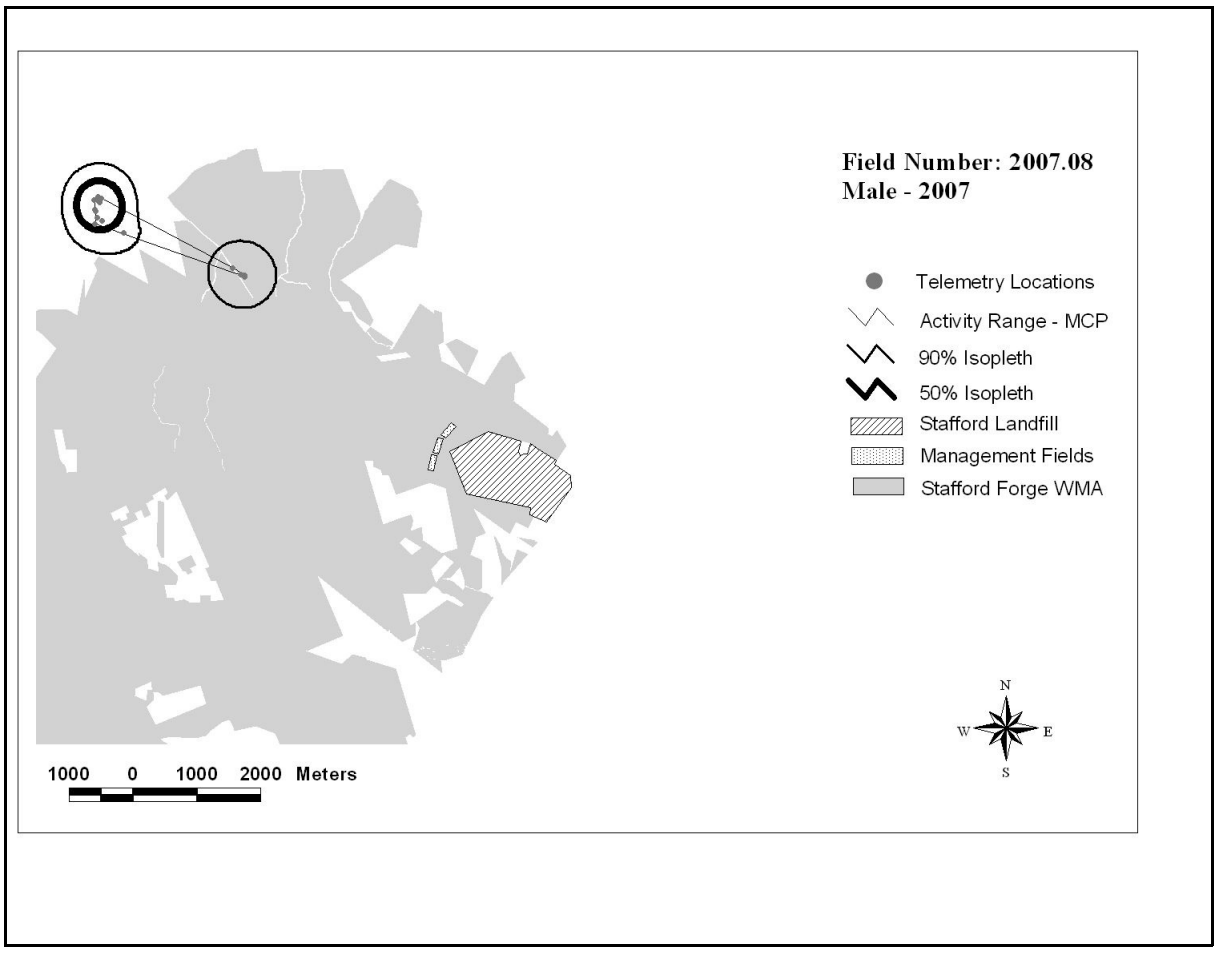


Figure 29. Radiotelemetry locations and activity range (minimum convex polygon and 50% and 90% isopleth from kernal analysis) for pine snake # 2007.08. The area used while being radiotracked in 2007 is 145.06 acres (59.07 hectares).

N. Pine Snake No. 2007.09 (♂) was relocated 52 times during the 2007 field season. It was originally captured by HA staff on 06/04/07 under a trash pile adjacent to a dirt bike trail NE of Gray/Hay road in heavily burnt pine forest. The snake was implanted on 07/19/07 and released the following day. This snake was relocated, all but a couple of times, in the burnt upland pine forest on the S/SW side of Hay/Gray road over 4 kilometers NW of the landfill. This animal hibernated in burnt upland pine forest in the NW section of Stafford Forge Wildlife Management Area.

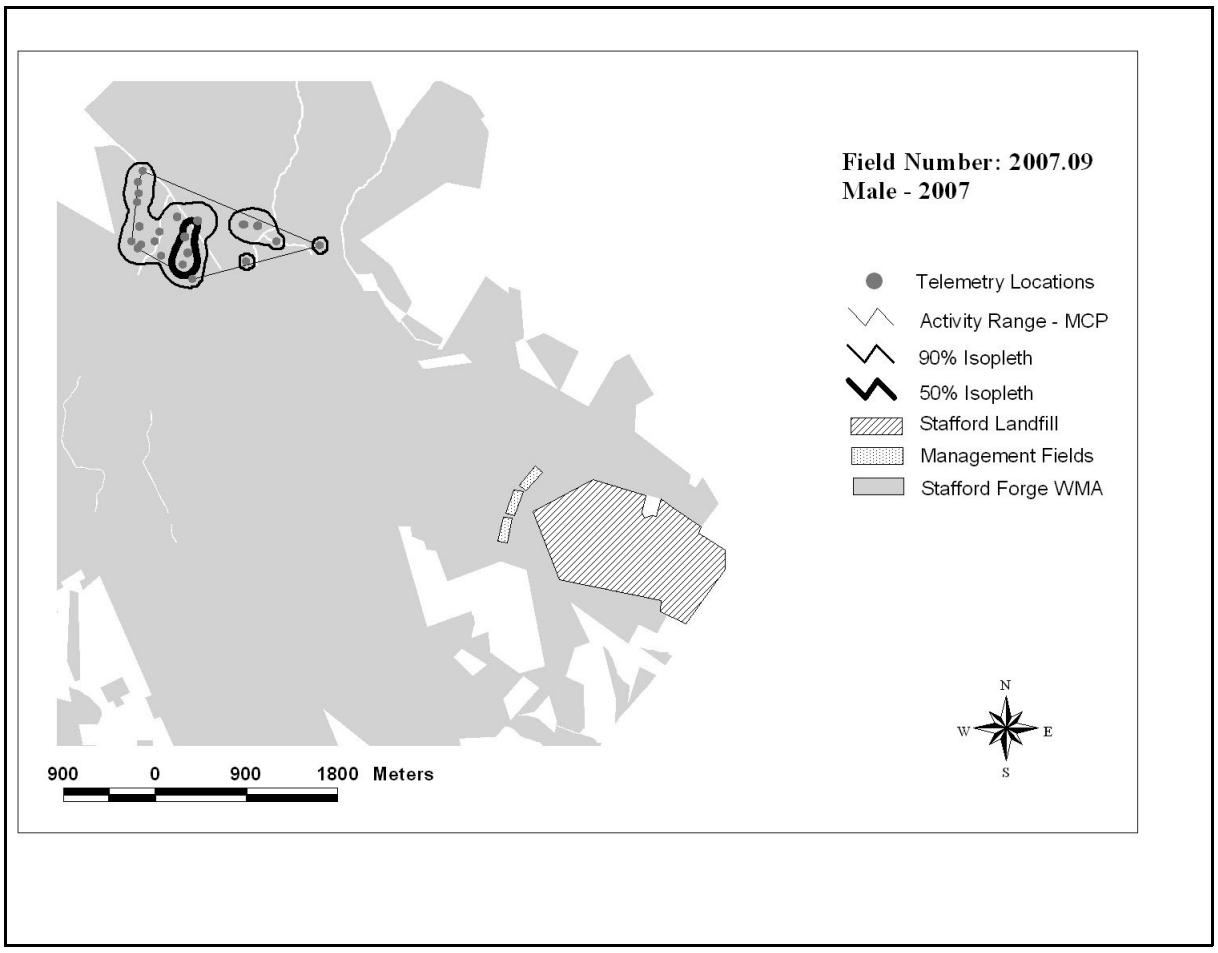


Figure 30. Radiotelemetry locations and activity range (minimum convex polygon and 50% and 90% isopleth from kernal analysis) for pine snake # 2007.09. The area used while being radiotracked in 2007 is 247.67 acres (100.23 hectares).

N. Pine Snake No. 2007.10 (♂) was relocated 63 times during the 2007 field season. It was originally captured by HA staff on 06/05/07 traveling near the cell tower on the Stafford Park construction site. This snake was implanted with a transmitter on 06/26/07 and released. This snake was released behind the management fields, because the habitat the animal was captured in was not suitable for re-release due to ongoing construction. From 06/29/07 to 07/19/07 this snake was consistently relocated near the management fields including a ten day period when it was concealed in a man made debris pile along the outer corral path of Den 4. During this time the snake was also observed inside a squirrel's nest approximately 9 meters up at the top of a pitch pine tree. 0n 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 this upland oak/pine forest within the boundary of Stafford Forge Wildlife Management Area.

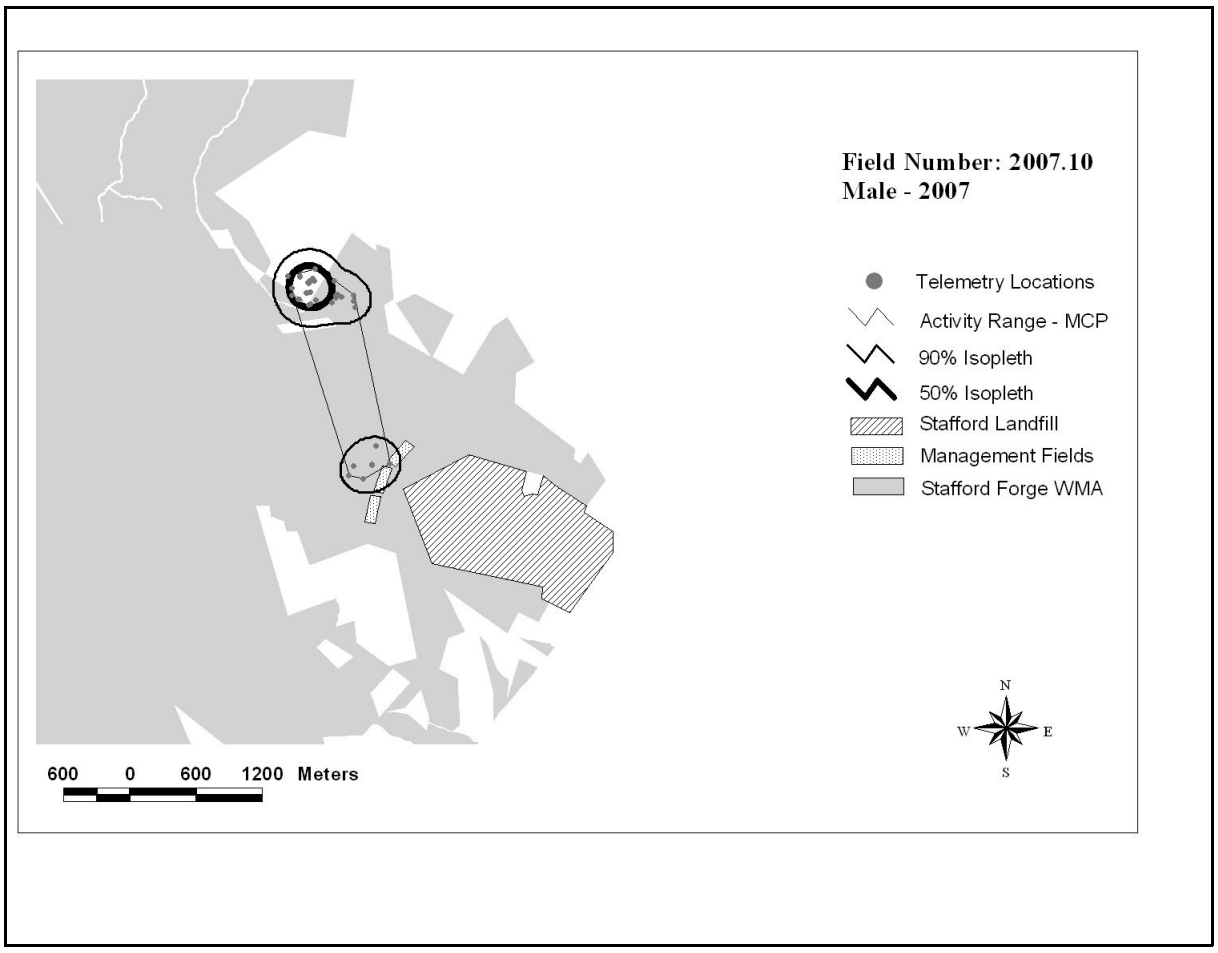


Figure 31. Radiotelemetry locations and activity range (minimum convex polygon and 50% and 90% isopleth from kernal analysis) for pine snake # 2007.10. The area used while being radiotracked in 2007 is 211.43 acres (85.57 hectares).

N. Pine Snake No. 2007.11 (♂) was relocated 67 times during the 2007 field season. It was captured by HA staff on 06/15/07 while radio-tracking pine snake 2006.34. It was captured traveling near the large glass dump pile approximately 1.5 kilometers S/SE of the construction site. After its release the snake spent the remainder of the field season south and southeast of the site. It was relocated in upland pine forest, oak/pine forest, or along the edge of a wetland corridor. A few relocations occurred within 50 meters of the southbound lane of the Golden State Parkway. This snake hibernated near 2007.14 in disturbed pitch pine forest approximately 3 kilometers SE of the site.

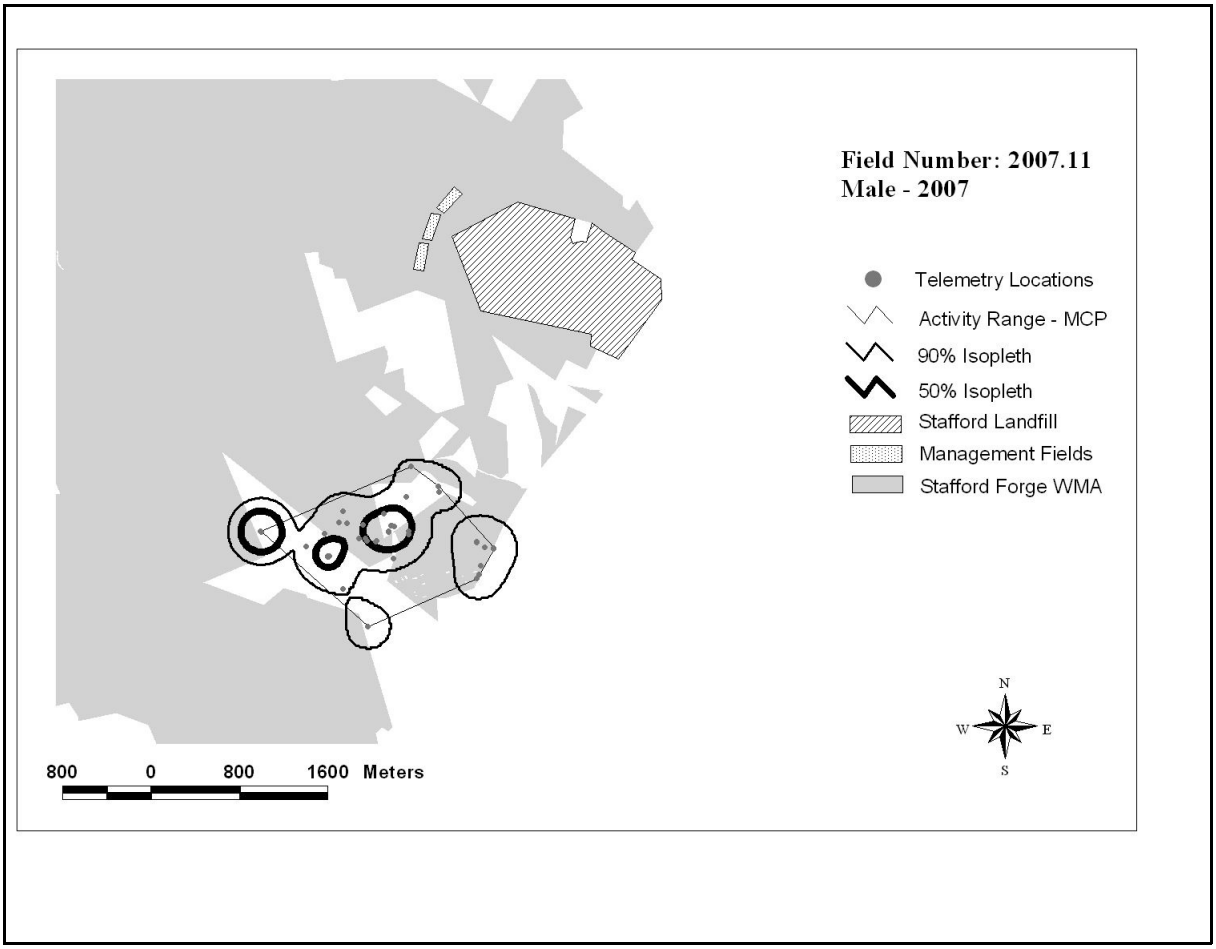


Figure 32. Radiotelemetry locations and activity range (minimum convex polygon and 50% and 90% isopleth from kernal analysis) for pine snake # 2007.11. The area used while being radiotracked in 2007 is 415.69 acres (168.22 hectares).

N. Pine Snake No. 2007.12 (♀) 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 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 (♀) 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 itself. This snake was found dead on 10/16/07 approximately 400 meters SE of its previous relocation. Two pieces of backbone were recovered, measuring 12 and 2 inches in length, as well as, the transmitter. The cause of death is unknown, but raptor predation is suspected.

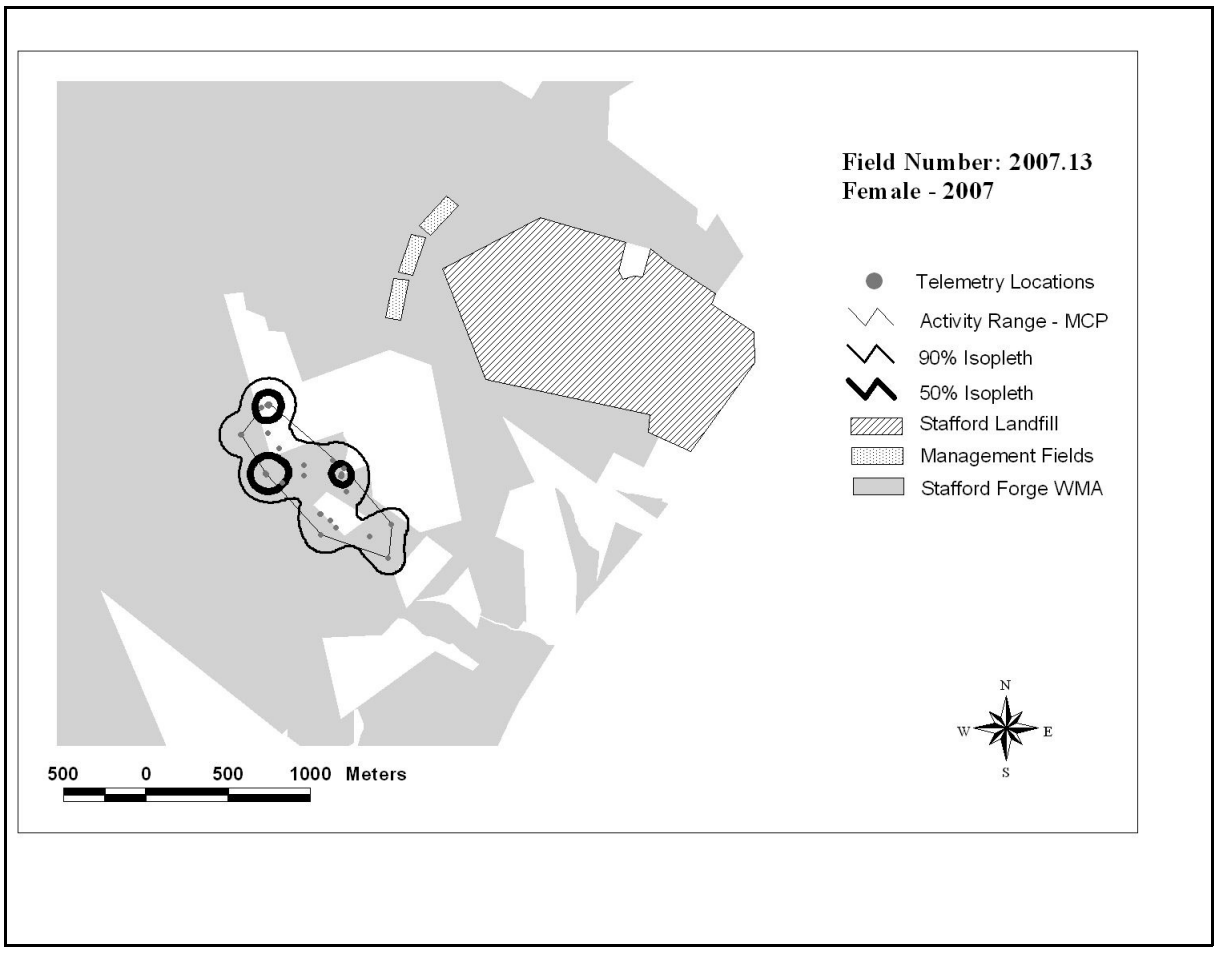


Figure 33. Radiotelemetry locations and activity range (minimum convex polygon and 50% and 90% isopleth from kernal analysis) for pine snake # 2007.13. The area used while being radiotracked in 2007 is 88.07 acres (35.64 hectares).

N. Pine Snake 2007.14 (♂) was relocated 38 times during the 2007 field season. It was captured on 08/11/07 on the large glass pile/dump south of the construction site. This was the same glass pile/dump were N. Pine Snake 2006.34 was relocated in or near several times over the season. This snake was implanted with a transmitter on 08/15/07 and released. This animal was relocated on a regular basis 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 were it was originally captured, as well as in the surrounding oak/pine forest. This snake, along with 2006.34, used a shingle pile adjacent to the glass dump when pre-shed. On 11/03/07 this snake made a large move of approximately 1.6 kilometers to the SW. It hibernated near 2007.11 in a previously disturbed pitch pine forest approximately 3 kilometers SE of the site.

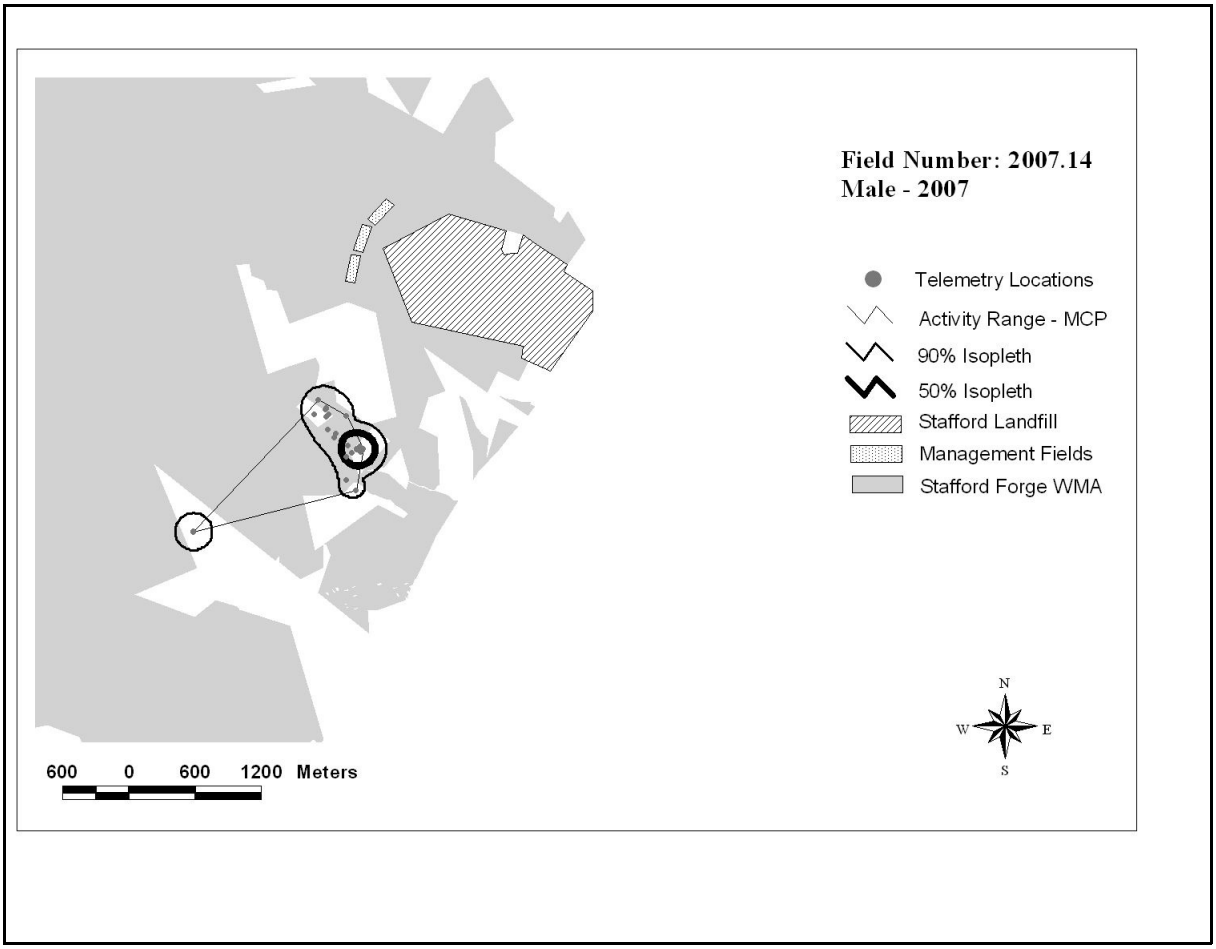


Figure 34. Radiotelemetry locations and activity range (minimum convex polygon and 50% and 90% isopleth from kernal analysis) for pine snake # 2007.14. The area used while being radiotracked in 2007 is 192.83 acres (78.04 hectares).

N. Pine Snake 2007.15 (♀) was relocated 18 times during the 2007 field season. It was 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 to late in the season to implant a transmitter, so an external transmitter was attached to the animal to find its natural hibernacula. The snake was released on 10/09/07. After its release this animal stayed south of the construction site and was often relocated within site 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 in an upland oak/pine forest south of the site on privately owned land. Earlier in the season N. Pine Snake 2007.05 was relocated in the very same stump hole.

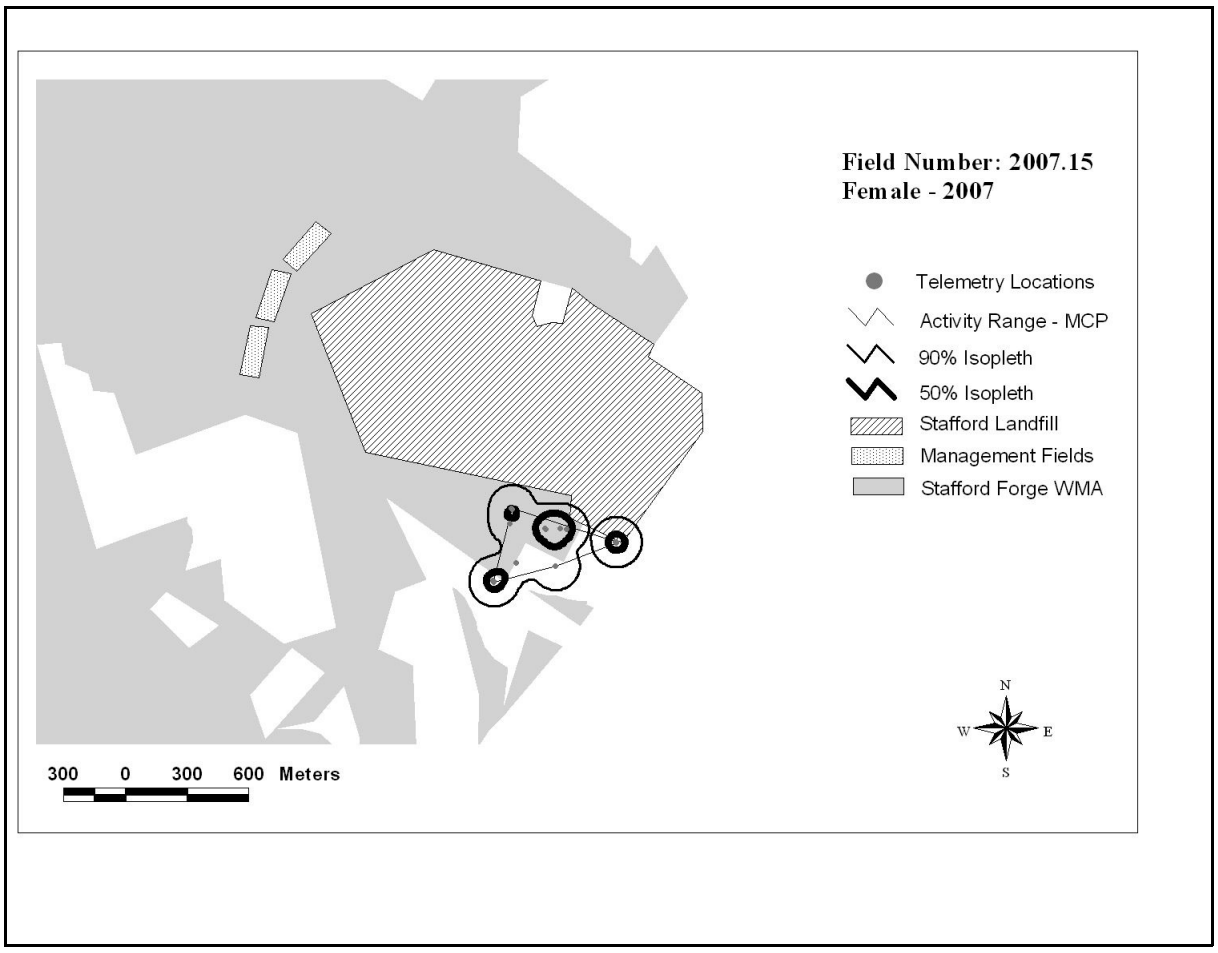


Figure 35. Radiotelemetry locations and activity range (minimum convex polygon and 50% and 90% isopleth from kernal analysis) for pine snake # 2007.15. The area used while being radiotracked in 2007 is 25.97 acres (10.51 hectares).

Habitat Use and Behavioral Analysis

Figure 36 is two graphs providing habitat use and behavioral comparisons of moved versus non-moved snakes in 2007.

Home Range Analysis Data

Table 2. Minimum Convex Polygon (MCP) Home Range Analysis Data 2007.

HA Snake ID #	Sex	# of Relocations	MCP area in Acres	MCP area in Hectares
2006.09	F	94	209.70	84.90
2006.11	M	89	485.15	196.34
2006.18	M	07	0.005	0.002
2006.21	F	90	1236.85	500.54
2006.26	M	78	91.16	36.89
2006.32	F	81	447.33	181.03
2006.33	F	87	302.48	122.41
2006.34	M	89	622.58	251.95
2007.02	M	08	3.07	1.24
2007.03	M	77	168.72	68.28
2007.04	F	56	291.39	117.90
2007.05	F	53	120.92	48.94
2007.06	F	18	0.27	0.11
2007.07	F	54	104.48	42.28
2007.08	M	22	145.96	59.07
2007.09	M	52	247.67	100.23
2007.10	M	63	211.43	85.57
2007.11	M	67	415.69	168.22
2007.13	F	39	88.07	35.64
2007.14	M	38	192.83	78.04
2007.15	F	18	25.97	10.51

Two-winter treatment snakes:

At the beginning of 2007 there were twelve adult snakes with radio-transmitters confined in the two winter treatments. Only six of these were being actively tracked by the end of the season. There were three major reasons for this, mortality, failure of transmitter, or removal of transmitter. Of the six snakes no longer being tracked, two died, two had transmitters fail, one had its transmitter removed for health reasons, and another was brought to HA's lab due to a migrating transmitter. The two pine snakes that were killed were 2006.06 and 2006.31. 2006.06 was killed by a red-tailed hawk in a den prior to the mesh netting being erected. 2006.31 was killed by the forest fire. The two snakes whose transmitters failed were 2006.15 and 2006.30. Both snakes were accounted for at one time or another during the field season and are currently hibernating in Den 4. HA will address the failed transmitters in the spring when the snakes egress from the dens. Pine snake #2006.19 had its transmitter removed due to health reasons and is currently hibernating in Den 1. Pine snake #2006.08 is currently over-wintering in HA's lab. This snake's transmitter was found to be migrating throughout the body cavity and HA must closely monitor the health of this animal. For the majority of the field season, corralled snakes were confined to the one acre corrals in Dens 1, 4, and 6. This was due to the destruction of the three acre corral walls and the vegetative cover inside the three acre enclosures by the forest fire on 05/16/07. None of the adult female snakes inside the corrals were found gravid during the 2007 season. Of the six corralled snakes that are still alive with functioning transmitters all are over-wintering in the two winter treatments. Three in Den 1, one in Den 4, and two in Den 6.

Free-roaming (one-winter treatment) snakes:

At the beginning of the season, eight adults that over-wintered in the artificial hibernaculum in 2006 egressed from the one-winter treatments and into Stafford Forge Wildlife Management Area. Only one of these snakes was lost during the season, being killed in the forest fire. No radiotracked 2006 females were recorded as being gravid and no signs of nesting activity were observed. Two of the 2006 snakes (2006.11 and 2006.26), both males, were relocated on the landfill site and had to be physically removed by HA staff. All seven surviving 2006 free-roaming snakes hibernated within the confines of Stafford Forge Wildlife Management Area or on private property bordering the management area. None of these snakes returned to the artificial hibernacula to over-winter. However, two 2006 adults (2006.11 and 2006.26) are hibernating within 75 meters of management field 3.

During 2007, sixteen new adult pine snakes (eight males and eight females) were captured on site, in the perimeter drift fence traps, or by Random Opportunistic Sampling (R.O.S.) methods in Stafford Forge Wildlife Management Area. Three of the females captured were gravid and were held within the artificial dens until egg deposition. Fourteen of the sixteen snakes were fitted with transmitters, twelve with internal and two with external, and released into the wild. The external transmitters were attached to snakes that were captured too late in the season to safely perform implantation surgery. The purpose of radio-tracking these snakes was to find their natural hibernacula. They will be recaptured during the spring egress and be implanted with internal transmitters. Four of the snakes captured in 2007, two males and two females, were killed during the season. Causes of death were determined to be raptor predation, automobile induced trauma, human induced blunt force trauma, and the forest fire. All snakes captured in 2007 over-wintered

within Stafford Forge Wildlife Management Area or on private property adjacent to the management area. No 2007 snakes attempted to over-winter in the artificial hibernacula, although one 2007 adult over-wintered 35 meters north of Den 6.

Juveniles and hatchlings

In 2006, seventy-one hatchling and five juvenile pine snakes were released into the artificial dens. All of these snakes were injected with PIT tags, but none had transmitters implanted. As a result, all 2007 records are based on the visual observations made by HA staff members of hatchling snakes inside the dens, caught in the den traps, or while random searching the habitat surrounding the management fields. Of the seventy-one hatchlings released in 2006, forty-one were observed during the 2007 season (57%). Three of the hatchlings were found deceased after the forest fire.

There are various reasons why some of the hatchlings were not observed in 2007. It is possible that some hatchlings died and were never found or identified. Raptor predation inside of the dens prior to netting construction, the forest fire, and failure to find a suitable overwintering spot inside the dens may have all contributed to hatchling mortalities. Also, during the season, the den traps were removed from the outside of the inner corrals allowing snakes to leave the dens on their own accord. It is possible that hatchlings and/or juveniles may have egressed from the dens during this period and were never observed again. A third possibility is that some hatchlings were simply never observed by HA staff. Young pine snakes are very secretive by nature and may have eluded detection. HA will continue to monitor the dens in 2008 and hope to account for those 2006 hatchlings and juveniles not observed this year.

As mentioned previously, HA staff captured three gravid females during the 2007 season. One snake was released into Den 1, another into Den 4, and another into Den 6 for egg deposition. Clutch sizes of two snakes are unknown. However, Robert Zappalorti observed a partially exposed egg on the SW side of Den 6. It was excavated and 8 eggs were in the nest chamber. The nest was covered with sand and concealed. All eggs were left in the field to hatch naturally.

From 09/21/07 to 10/02/07, HA staff caught a total of ten new hatchling pine snakes inside the dens, five in Den 4 and five in Den 6. No hatchlings were captured in Den 1. It is possible that the gravid female released into Den 1 laid infertile eggs. Regardless, Den 1 failed to yield any successful 2007 hatchlings. All captured 2007 hatchlings were injected with PIT tags and released outside of the dens into Stafford Forge Wildlife Management Area. One 2007 hatchling (2007.21) was caught trying to enter Den 2. This snake was released into the den and over-wintered there. All other 2007 hatchling over-wintering sites are currently unknown.

Use of Enhanced Habitat

In accordance with the management plan, steps were taken to enhance the habitat available in and around the management fields to make it more suitable for pine snakes, as well as other species of wildlife. A portion of this habitat enhancement included the creation of sand and log brush piles and berms along the perimeter of the management fields, the outer den corral paths, and the access road. These earthen berms and piles were created to provide cover, shedding, and basking areas for snakes (**Figure 37**). Over the duration of the season a total of six radio-tracked pine snakes were relocated inside of, on top of, and within a few meters of these berms and piles. Many of these snakes were relocated inside the earth structures for extended periods of time and on multiple occasions throughout the season. Four of these snakes were moved snakes from 2006 and two were non-moved animals caught during 2007. Four snakes (2006.09, 2006.11, 2006.26, and 2007.04) were relocated inside the earth berms that separate the management fields from the forest. Almost all of these relocations occurred in the earth berms along management field three.

Environmental Monitoring

HA collectively totaled over 900 hours of monitoring in 2007. This includes monitoring of habitat alteration (forest clearing, stump pile grinding, top soil stripping, etc., see **Figures 38** and **39**) as well as monitoring the snake populations withheld in the management fields (checking egress/ingress traps, searching the corrals for hatchling/yearling snakes, fixing damage on corral fences, etc.). Another important aspect is monitoring the health of the enclosed animals. Regular feedings were conducted during the active season to supplement the diets of animals restricted from foraging for food beyond the corral walls. The onsite environmental monitoring was performed by one, full-time HA staff member while snake management field monitoring was conducted by many HA employees.

Management Field Monitoring

Throughout the duration of 2007, HA staff continuously monitored pine snake activity in and around the management fields. During the spring egress and fall ingress HA staff checked den traps on a daily basis to account for any snakes attempting to leave or enter the dens. HA staff randomly searched the corrals on a regular basis for snakes basking, moving, or concealed outside of the hibernacula. This allowed HA staff to assess the health of the corralled snakes, account for any snakes that had not been previously observed, record any mating or nesting activity, and monitor behavioral activity. The earthen berms along the edges of the management fields were often searched in an attempt to capture/document any pine snakes that may have been using these structures.

HA also performed routine maintenance on the dens and corrals throughout the year. Weather and environmental conditions all contributed to the deterioration of corral structures. HA staff repaired corral walls, replaced corral traps, and repaired ripped netting as needed during the season. Following the forest fire on May 16, 2007 HA attached traps along the outside and inside of the three acre corral walls of Dens 1, 4, and 6. HA hoped to capture and account for hatchling or juvenile snakes that had been confined inside the three acre enclosures pre-fire.

HA staff also monitored the management fields to discourage and prevent trespassing. HA observed unauthorized personnel on the management fields on at least one occasion during the season. Although no serious vandalism occurred, HA staff did observe footprints around the den structures and at least one shade board was tampered with.

DISCUSSION

Fire Effects

The fire on May 16, 2007 killed a total of 5 study snakes, three adults and two yearlings. This poses some new questions. How does this fire affect the study? How has the fire impacted the study population? Does this rapid change in structural habitat alter the behavior of the northern pine snake whose home range lies within the impacted area? Are there benefits to pine snakes from fire occurrences within its habitat? Although well studied, it is unclear how specific reptiles respond to fire due to the variability of circumstance (fire intensity, habitat availability) (Bamford, 1985; Braithwaite, 1987; Smith et al, 2001). It is known that vertebrate animals such as deer or mice will attempt to outrun the front lines of a fire (Erwin and Stasiak, 1979) and birds will attempt to out-fly it, but how do snakes escape fire in their habitat?

Erwin and Stasiak, 1979, found both dead and injured bull snakes (currently *Pituophis catenifer sayi*, previously, *Pituophis melanoleucus sayi*) with the cause directly related to fire. HA found both dead and injured pine snakes immediately after the fire in a similar fashion. Injured pine snakes had burns on ventral, dorsal, and head scales. HA also found three ribbon snakes (*Thamnophis s. sauritus*), an eastern garter snake (*Thamnophis s. sirtalis*), two northern black racers, and a hatchling eastern hognose snake all killed by fire. One of the northern black racers was a gravid female. She was found in a discarded metal shutter with desiccated eggs escaping her body cavity from what seemed to be a pressure opening in her lower half.

The overall mortality rate (from fire) of the adult study population is low. HA must exclude the yearling snakes when assessing this rate due to their dispersal in the forest and the subsequent lack of monitoring capability. Of all radiotracked snakes, 85% survived the fire. Two of these animals were injured, having minor burns. In a study conducted by Rudolph et al (1998) they found that Louisiana pine snakes (*Pituophis melanoleucus ruthveni*) "are not at excessive risk of death or injury because of frequent fire in fire climax pine communities". This study observed three different pine snakes as a prescribed fire approached and documented their methods of evasion. Prior studies of fire impacts on small vertebrates suggest that the fire intensity has caused a greater mortality/injury risk for small vertebrates (Braithwaite, 1987; Erwin and Stasiak, 1979; Smith et al, 2001), including pine snakes (Rudolph et al, 1998). Through radiotelemetry, HA has suggested that pine snakes, when on the surface, are often within a close distance to an underground refuge (mammal burrow, stump hole, hibernaculum, etc.). Also, when disturbed, pine snakes recognize their habitat and move deliberately towards and into these refugia. Therefore, a secondary factor for snake mortality during fire could be the snake's activity at the time of the fire's approach. A snake in the process of a large move from one recognized area to another may find itself without a suitable avenue for escape. The literature is limited, however both successful evasion (Rudolph et al 1998) and snake mortality (Russell et al, 1999) have been documented where a snake is in transit when fire approached.

In the case of the successful retreat, the animal was observed to perform a "rapid search for a subterranean retreat", implying higher risk of injury or mortality than those animals observed on the surface motionless near known underground retreats.

The May 2007 fire burned very hot as it passed through the study area, crowning in most sections. The intensity of the fire was likely to have a key role in killing these snakes, as well as other vertebrate species found burned and/or dead (Smith et al 2001). This particular area had not been recently fire-managed, therefore, the fuel load was high, supporting a fire that burned very hot. This offered little refugia on the surface for animals, as fallen logs, trees, and brush piles burned thoroughly. Rock and metal debris piles were heated up to temperatures too hot for vertebrates to withstand without suffering burns or death. This was determined by the discovery of cottontail rabbit, white-footed mouse, northern fence lizard, northern black racer, and eastern box turtle all found dead in or under metal/rock debris piles after the fire (McGraw, pers. obs.). Two pine snakes (adults) were found concealed within logs thoroughly burned and deceased. The other three northern pine snakes (1 adult, 2 yearling) were found dead on the surface. It is likely that these animals did not find an underground retreat fast enough to escape the smoke and flames. The cause of death of these animals seemed to be severe burns or asphyxiation in all species. Bird species found dead after the fire include blue-gray gnatcatcher (*Polioptila caerulea*), pine warbler (*Dendroica pinus*), American robin (*Turdus migratorius*), and rufous-sided towhee (*Pipilo erythropthalmus*) (**Figure 40**). Many burned nests of rufous sided-towhee were observed, as this bird nests on or near the ground. A mallard nest was also found burned with spoiled eggs inside. Whitetail deer were found dead in large numbers (20-25) around a pond in an area where the fire burned very hot, incinerating all surrounding vegetation. Also, whitetail deer with burns on their sides and faces were observed in the weeks following the fire drinking from the storm water basins onsite (McGraw, pers. obs.). A large number of eastern box turtles were found dead or injured after the fire. As Rudolph et al (1999) states, "Babbitt and Babbitt (1951) and Folk and Bales (1982) reported that box turtles (*Terrapene c. carolina*) and eastern mud turtles (*Kinosternon s. subrubrum*) survived fires by burrowing into the soil." Many of the dead box turtles found had the anterior portion of their body in the soil or leaf litter. It appears as if these animals were attempting to burrow into the soil when the fire overcame them. Again, perhaps the fire burned too intense for these animals to respond effectively. Some box turtles that survived show burns only on their posterior or anterior (**Figure 41**), thus supporting this theory.

Despite the individual mortalities, it is likely that the fire will be beneficial to most local vertebrates (Smith et al, 2001), including pine snakes. The New Jersey Pine Barrens is a historically fire-maintained macro-habitat (Forman, 1998). Animals that have adapted to this habitat have also adapted to the cyclic fire regime that sustains this ecosystem. Radiotracked pine snakes in 2007 have proven to capitalize on what little surface cover is left in severely burned areas (**Figures 42** and **43**). Fire-burned stump roots causes newer, deeper avenues into underground refuges. The natural vegetative succession will provide a plethora of fast growing, seed producing grasses, promoting small mammal rebound. The pitch pine trees of the New Jersey Pine Plains located west of the site in Warren Grove bear nearly 100% cones that are serotinous (Forman, 1998), dispersing seed only after exposed to intense heat, such as fire. This percentage of serotinous cones decreases projecting outward from the Pine Plains, but the SBP site bears these serotinous coned pine trees to some extent as well. This is a direct adaptation to a fire-frequent situation.

The day after the fire, pine warblers were observed feeding on the newly opened pine cones yielding pine seeds. New rufous-sided towhee nests were observed six days after the fire under charred logs on the forest floor (**Figure 44**). The fire has reduced the fuel load, ensuring a less intense fire if prescribed burns are incorporated into the future management of this section of forest.

It is uncertain if the fire has caused any adverse impact on the overall health of the pine snake population in Stafford Forge WMA. Through intensive, long-term radiotelemetry, HA will further understand any significant changes in pine snake behavior directly related to the fire and its subsequent alteration in structural habitat.

Den Use

As previously mentioned, no one-winter treatment snakes returned to the artificial hibernacula. These pine snakes were shifted within their home ranges, not relocated. Therefore, there is a strong possibility for habitat recognition upon egression into the forest from the one-winter treatment dens. All of these animals had previously overwintered in natural dens located within the surrounding habitat. It is likely that these animals have returned to previously used den sites. This does not mean that in the future the artificial hibernacula will not be utilized as over-wintering sites. Other artificial hibernaculum constructed by HA have, over time, become an integral part of the denning network for pine snakes (Frier and Zappalorti, 1983; Zappalorti et al, 1994). The artificial hibernacula constructed by HA in Stafford Forge WMA will more than likely become an important and integral part of the habitat used by not only the study animals, but other snakes as well. Once the dens are more accessible to snakes (removing the hardware cloth corrals and the growth of successional vegetative cover in the management fields), they will be more likely to utilize the den structures for various purposes including concealment, ecdysis, nesting, summer denning, and overwintering.

Post-Release Care of Snakes

Animals withheld in the den corrals in 2007 had to be provided ample prey items in order to maintain healthy body weight and proper nutrition levels. To accomplish this, HA set up Sherman traps to catch small mammals (white-footed mouse, specifically) which where checked daily. Upon the capture of a small mammal it was collected and released into a den corral (provided it was a common species). These prey items were distributed equally throughout the two-winter dens in 2007. This method was effective. HA observed pine snakes eating white-footed mice within the corrals (McGraw, pers. obs.). HA staff also fed corralled snakes frozen/thawed lab mice (**Figure 45**). This was most important for hatchling snakes due to their size limiting their potential for feeding opportunities from the released wild mice (**Figure 46**).

Use of Enhanced Habitat

As mentioned previously, four radio-tracked pine snakes were found on multiple relocations to be utilizing the man-made earth berms separating the management fields from the surrounding forest. Along with utilizing the earth berms around the management fields radio-tracked snakes were also found to use other man-made brush piles created around the site. Four snakes (2006.09, 2006.34, 2007.03, and 2007.10) were relocated in man-made earth piles created when the outer corral paths were cleared. One snake (2006.11) was relocated inside a man-made earth pile along the access road. These man-made earth berms and piles form an integral part of the habitat available to the snakes. These structures were important in providing the snakes and other animals with refuge during the fire. They were able to find shelter deep inside the berms and brush piles away from the flames. (HA staff, per. obs.) The brush pile and berms were just as important after the fire, providing the snakes with shelter and cover since most of the forest vegetation was consumed. Also, two radio-tracked snakes were positively identified as pre-shed when located on or near the earth berms. It is highly likely that these snakes were using the earth berms as shedding (ecdysis) stations. 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 as well. The earth berms and piles also provide ideal habitat for prey items such as white-footed mice.

Another intended goal is for the management fields to eventually provide suitable nesting habitat for pine snakes. In 2007, the non-corralled portion of the fields were not vegetated, offering no cover for shade or concealment, thus, no nesting snakes used the fields. Once the native grasses grow and create a grassy meadow habitat, the potential for nesting will greatly increase. The artificial den mounds currently within the corrals also provide potential for nesting (Zappalorti and Reinert. 1994).

Conclusion

Pine snakes (adults, sub-adults, and hatchling) can successfully overwinter in the artificial dens designed by HA. No moved snakes that have been released into the wild (one-winter treatment animals) returned to the artificial dens to hibernate in the fall of 2007. It remains to be determined whether these animals will return to use these dens in subsequent years. HA will closely monitor the six artificial dens for use by the study animals, as well as other pine snakes and different snake species over the next six years. Having only one year of data, it is too early to generate statistical comparison of any worth, however, moved snakes were found to be on the surface more than non-moved snakes. Kernal home range analysis has determined no marked difference in spatial usage between moved and non-moved snakes. The following six years of radiotelemetry will determine the fidelity to these particular home ranges.

In 2007, two radio-tracked adult pine snakes continued to attempt to enter the property/construction site. Both were returning to the same buried concrete pile in a common reed field along the northwest edge of the property. This area is now part of the licensed landfill and is buried with trash and dirt.

It is too early to compare Treatments A (one winter) and B (two winter) yet. Treatment B and Treatment C (withheld in lab in 2006-2007 winter) animals will be egressing from the artificial dens in the spring of 2008. After the 2008 field season, a comparison of the one and two-winter treatments will begin. Over the next six years HA will determine if these animals show any difference in den site fidelity with respect to the artificial dens.

HA will conduct pine snake nest-search surveys for the next six years in the management fields to determine if female pine snakes use the habitat provided for nesting. Based upon similar pine snake studies at the Audubon Sanctuary in western Berkeley Township of Ocean County, HA predicts that some pine snakes will eventually nest on the Stafford Forge WMA management fields.