

***2011 Annual Northern Pine Snake Monitoring and Radio-tracking
Report Conducted at the Stafford Business Park,
Stafford Township, Ocean County, New Jersey***



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To

The Walters Group

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INTRODUCTION

Herpetological Associates, Inc. (hereafter HA), has been monitoring northern pine snakes (*Pituophis m. melanoleucus*) at a commercial and residential development known as the Stafford Park Redevelopment property (hereafter SPR property) in Stafford Township, Ocean County, New Jersey. The SPR property is 370-acres in size (**Figure 1**). This is HA's fifth annual progress report on this long-term investigation. The framework for this project is guided by the June 28, 2006, Memorandum of Agreement (hereafter MOA) which was made between Walters Homes, Inc. (hereafter Walters), Ocean County, Stafford Township, and the New Jersey Pinelands Commission (hereafter the Commission). As part of its responsibilities, Walters closed and excavated the old unlicensed landfill on site and used the excavated materials to properly close and cap the new licensed landfill located on the redevelopment property. This action was taken because the unlicensed landfill was contaminating ground water and the nearby, Mill Creek.

BACKGROUND INFORMATION

Threatened and endangered species surveys initiated at the SPR property in April of 2004. These surveys, which were conducted by EcolSciences, Inc., revealed the presence of four state-listed plant and wildlife species, one of which is the northern pine snake, a state-threatened species listed by the New Jersey Department of Environmental Protection. It occurs on and in the vicinity of the SPR property. Considerable effort was put forth surveying the SPR property site for pine snakes during the 2004, 2005 and 2006 activity seasons. In May of 2006, HA was asked to assist with the ongoing plant and wildlife species research. Through these intensive surveys, it was learned that the SPR property provided critical foraging, nesting and overwintering habitat for northern pine snakes. It was determined that the pine snake population required a long-term management and conservation study plan. Walters funded the planning and writing of specific management plans regarding the mitigation and direct impacts to pine snakes, southern gray treefrogs (*Hyla chrysoscelis* - endangered), and two rare plant species, Knieskern's Beaked Rush (*Rhynchospora knieskernii*), a federally-threatened and state-endangered sedge, and Little Ladies'-tresses (*Spiranthes tuberosa*), an orchid on the Commission's list of protected plants. A final progress report for southern gray treefrogs and rare plants were provided to the Commission by HA in 2008. HA and Dave Golden, Senior Zoologist with the New Jersey Department of Environmental Protection's Endangered and Nongame Species Program (hereafter the Department), designed and wrote the conservation, mitigation and management plan for pine snakes as outlined in the June 28, 2006 MOA. In accordance with the MOA, all funding for the conservation plans were provided by Walters.

On December 4, 2006, HA and the Department submitted the final Plan to the Commission entitled: "A Northern Pine Snake Management and Conservation Plan, and Radio-tracking and Monitoring Plan for Stafford Business Park and Stafford Forge WMA." The pine snake plan consisted of two parts, a Relocation and Management Plan (**Part I**), and a Radio-tracking and Monitoring Plan (**Part II**). The Plan was fashioned after similar snake conservation studies in the literature (Griffith et al, 1989, King et al, 2004, King and Stanford 2006, Zappalorti and Golden 2006, Teixeira et al, 2007). The Plan was approved by the Commission and Walters was allowed to proceed with redevelopment and new landfill construction, provided the research and conservation plans were followed. Three pine snake management fields with two artificial snake hibernacula were built in Stafford Forge WMA for the shifted portion of the population. HA initiated a seven-year pine snake monitoring program. Walters began residential and commercial development in 2007.



Figure 1. A 2009 aerial photograph showing a western view of the study site and the various commercial, township and county buildings that were constructed on the eastern and central portions of the SPR property. The licensed landfill is centered on the western portion of the property (the open grassy fields at the top left of the photo), and retention basin D is located in the extreme western portion of the site. The three pine snake mitigation and management fields are due west from the edge of the site. The perimeter exclusion drift fence and traps that surrounded the SPR property were removed in the winter of 2010/2011, because the trapping study was completed. Source: Walters, Inc.



Figure 2. Google Earth aerial photo showing the three pine snake management fields at Stafford Forge WMA. There are two artificial dens on the west side of each field. Notice the elongated circles coming from each field in a westerly direction, these were the former 3 acre summer holding corrals that were burned by a forest fire on May 16, 2007, rendering them unuseable while killing four of our study snakes. The southern gray treefrog breeding pond is on the western edge of the SPR property.

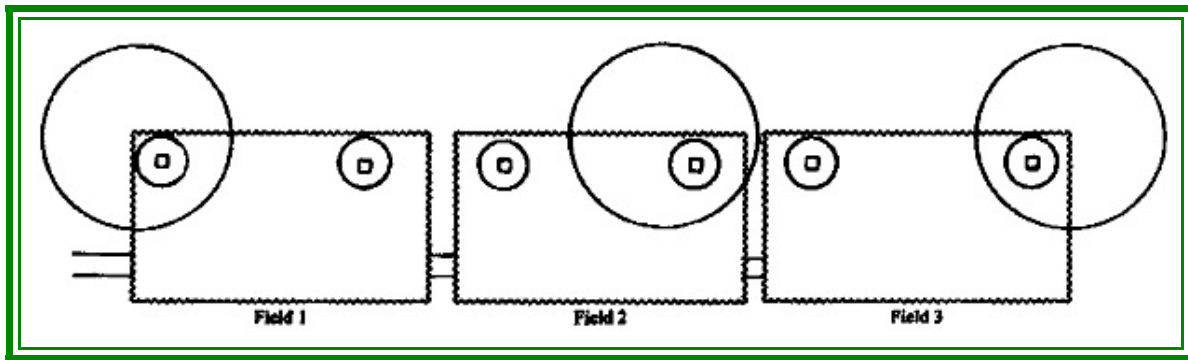


Figure 3. Diagrammatic drawing of the three Pinelands Commission approved snake management fields that were constructed on Stafford Forge WMA in the Fall of 2006 (see Legend for more details). Source: Zappalorti and Golden 2006).

Figure Legend: □ = Artificial Hibernaculum, ○ = Small Winter Fence, ○ = Large Summer Holding Corral.

Note: Diagrammatic drawing is not to scale. See description in the section below for the size details under the heading titled “Creation of Management Fields and Artificial Dens.”

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

According to Zappalorti and Golden’s 2006 Management and Conservation Plan, the long-term field studies and radio-tracking monitoring program would address and possibly answer the following six research questions:

1. Can adult and hatchling northern pine snakes establish themselves and overwinter successfully in constructed artificial hibernacula after being shifted to a different area within their known activity range?
2. Will non-shifted northern pine snakes (or other snake species) from the existing Stafford Forge Wildlife Management Area population begin to use the artificial hibernacula constructed at the three management fields on their own?
3. How do the spatial movements and other behaviors (*e.g.*, habitat use, foraging, mating, nesting, and denning) of the shifted pine snakes differ from the non-shifted pine snakes?
4. Do pine snakes from this population (both those shifted to the management fields and others) attempt to move back onto the redevelopment area of Stafford Township Business Park during the construction period, and if so, does this tendency diminish over time?
5. Will a higher percentage of northern pine snakes (adults and juveniles) return to, and overwinter in, the artificial hibernacula when they are kept in an enclosed area around the hibernacula and fed for two winters versus only a single winter?
6. Will shifted and non-shifted gravid (carrying developing eggs) female northern pine snakes from this population begin using the three management fields as nesting habitat in future years?

MATERIALS AND METHODS

HA Staff and NJDEP Researchers

There were numerous tasks to be performed and data to be collected during the 2011 field season at Stafford Forge WMA and the SPR property. The following HA staff members were present during some, or all of the wildlife monitoring and surveys: David Burkett, Dave Emma, Robert Hamilton, William Callaghan, Raymond Farrell, Matthew McCort, David Schneider and Robert Zappalorti. Additionally, Division of Fish and Wildlife staff, Dave Golden and Kim Korth advised and assisted with various tasks throughout the 2011 field season.

CREATION OF MANAGEMENT FIELDS AND ARTIFICIAL DENS

The relocation and management phase of the conservation plan included habitat manipulation for pine snakes that were collected and shifted from the SPR property (Kingsbury and Gibson 2002). HA and the Division supervised the creation of three pine snake management fields (hereafter MF 1 through 3), at preselected suitable sites within Stafford Forge WMA. Each cleared field measures approximately 300 feet wide by 800 feet long in size (or a total of 5.5-acres, see **Figures 2 and 3**).

These three 5.5-acre fields were meant to replace the open grassland habitat that was lost on the old SPR property (e.g., the two winter dens, the foraging habitat and nesting areas on the old unlicensed landfill). Two snake dens (artificial hibernacula), were constructed on each management field, approximately 350 feet from one another (Gillingham and Carpenter 1978, Frier and Zappalorti 1983, Zappalorti and Reinert 1994, Zappalorti and Golden 2006) (**Figure 4**). Each hibernaculum was encircled with a one-acre fence to keep the snakes within the den enclosures. The circular fences stood 5 feet in height. Three of the dens (AH 1, 4, and 6) had a larger, 3-acre perimeter fence for holding the pine snakes over a twenty month period (1.5 years). As part of this experiment, a total of 100 pine snakes were released into the dens in the fall of 2006 (25 adults, 4 sub-adults and 71 hatchlings (**Table 1**).

Table 1. Random Distribution of the 2006 Shifted Pine Snakes that were Released into Six Artificial Dens (Treatments A and B), and Non-random Assignment into Treatment C.

Winter Treatments	Den Number	Adult Males	Adult Females	Juveniles	Hatchlings	Totals
B = Two Winters	1	1	1	1	11	14
A = One Winter	2	2	2	0	13	17
A = One Winter	3	2	1	1	11	15
B = Two Winters	4	2	1	0	12	15
A = One Winter	5	1	1	2	11	15
B = Two Winters	6	2	1	0	13	16
C = One Winter in HA's Laboratory		3	5	0	0	8
Three Treatments		13	12	4	71	100

These snakes were randomly selected for distribution into Treatments A and B (A = one-winter treatment and/or B = two-winter treatment). The third treatment, Treatment C (the laboratory treatment), was not originally planned, but was created out of necessity after it was determined that 8 of the pine snakes were not healthy enough to be released in the fall of 2006. Because of the eight snake's poor health, unlike Treatments A and B, these snakes were not randomly assigned to Treatment C and were held in HA's laboratory for one winter. All 8 snakes placed in Treatment C were determined to be healthy enough to be released into the two-winter treatments in the spring of 2007. They too were monitored via radio-telemetry through the 2007, 2008, 2009, 2010 and 2011 activity seasons.

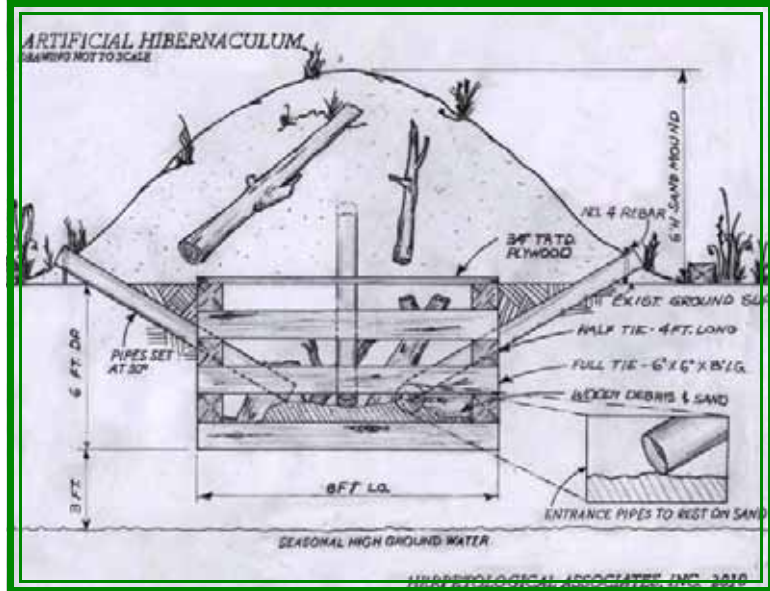


Figure 4. Diagrammatic drawing of an artificial snake hibernaculum designed by Zappalorti and Reinert (1998). This type of snake den has been used successfully for pine snakes and corn snakes at the Crossley Preserve and at the New Jersey Audubon, Hovnanian Preserve. Timber rattlesnakes have used this type of den at Greenwood Forest WMA.

Another portion of the relocation and management phase of the conservation plan involved enhancing existing habitat within Stafford Forge WMA for pine snakes. This included the construction of 6 foot high earthen berms along the edges of the three fields and large earthen and wood debris piles within the center of the fields. These earthen berms were constructed out of A-horizon sand, stumps, logs and brush. The fields provide pine snakes with forest-edge habitat suitable for basking and resting (Burger and Zappalorti 1988a, Zappalorti and Burger 1985). The fields are also open, with sandy areas that provide potential nesting habitat for female pine snakes (Burger and Zappalorti 1991). As part of the habitat enhancement, HA and the Department planted grasses on the fields to replicate the lost landfill field habitat. Open grassy fields have been shown to be good nesting and foraging habitat for northern pine snakes (Burger and Zappalorti 1986 and 1991). For greater detail on the success of the habitat enhancement, please refer to the results and discussion section of this report.

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



Figure 5. A top view of one of our study snakes that had severe burns across its mid-dorsal scales from the May 16, 2007, forest fire. Photo by Bob Hamilton, HA Staff.

ONSITE MONITORING

One of HA's tasks was to act as environmental monitors during various construction activities on the SPR property. During any habitat alteration, a qualified HA staff member was present to examine the area for any reptiles or amphibians that may have been present within the habitat. Any animals found during these activities were collected, documented and released in the nearest section of protected Stafford Forge WMA forest.

The clearing of the forest within the SPR property boundaries was mostly completed in 2006 and 2007, however some additional clearing took place in 2011 along the southern portion of the SPR property. This area was cleared for the beginning development phase of the new Stafford Park Preserve Luxury Apartments. Pertinent data with respect to environmental monitoring is further explained in the results section of this report.

HABITAT EVALUATION

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

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

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

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

REPTILE AND AMPHIBIAN SURVEY TECHNIQUES

Reptiles and amphibians are often difficult to census due to their highly secretive nature and ability to remain hidden for long periods of time. Environmental conditions such as ambient temperature, precipitation, soil moisture, relative humidity, light intensity, wind, and season have strong influences on reptile and amphibian activity patterns (Vogt and Hine 1982). Unsuitable weather conditions may lead to increased fossorial behavior (burrowing), markedly reduced activity, shifts in habitat usage, and/or estivation (dormancy during hot and dry conditions) (Greene 1997). Therefore, the use of several sampling techniques which take into account the various aspects of an animal's biology will often result in the best assessment of the target species relative abundance (Zappalorti and Torocco 2002). The following visual search methods were performed.

Random Opportunistic Sampling (ROS)

A simple method used by the trained herpetologist, ROS was employed in conjunction with other sampling techniques on the study site. Habitat that showed potential for target species were searched. This search method is not constrained or standardized in time transects, but instead relied on the experience and professional judgement of the investigators. This method is effective if there are no time constraints, however detailed surveys will be performed as a follow-up (Campbell and Christman 1982; Karns 1986). Qualitative impressions were determined as to the relative abundance and habitat use of certain species during ROS. All wildlife encountered was recorded to supplement the species list generated by other field methods (Zappalorti and Torocco 2002).

Time-constrained Searching (TCS)

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

Diurnal and Nocturnal Road Cruising

Roads which border potential habitat often yield both living and road-killed animals (referred to as Dead On Road or DOR), reptiles, amphibians and other animals. Identification of species found while "road cruising" can provide useful information on migration routes, activity patterns, and habitat utilization/partitioning. The basic presence or absence of a species in a particular area can also be determined by the identification of their remains alone. Road cruising was used passively,

such as while driving to and from the site or while driving/walking to and from areas on the site, or it was initiated as a specific surveying technique. This method involved driving a vehicle at slow speed along sand trails and paved roads at various times of the day and/or night. Road cruising is often highly productive on warm, humid or rainy spring nights, or during other periods of high activity. Animals moving across roads and those killed were collected and/or identified (Campbell and Christman, 1982; Karns, 1986; Zappalorti and Torocco 2002).

Pine Snake Nest Survey

Surveys for pine snake nests were conducted visually. Typical pine snake nesting habitat consists of sandy uplands with few shrubs or tree cover and characteristic plants such as Pennsylvania sedge (*Carex pennsylvanica*) and golden heather (*Hudsonia ericoides* - Burger and Zappalorti, 1986) (Figure 6). Pine snake nests can be located by the characteristic sand dump pile left by the female after nesting (Burger and Zappalorti, 1991). Additionally, pine snake nesting areas can be found by locating the hatchlings (or their fresh shed skins) in early September when the effects of weather makes the sand dump piles difficult to find



Figure 6. Radio-tracked pine snake 2008.03's nest site within the Stafford Forge WMA. The location is an open sunny area approximately 13 meters in diameter and is dominated by *Hudsonia* and *Carex pennsylvanica*, has loose sandy soil, and lacks trees. The elongated white sand fan has the pine snake's nest opening, on the left. Photo by Bob Hamilton, HA Staff.

(Burger and Zappalorti 1991, Burger and Zappalorti 2011) (Zappalorti, personal observations). The primary goal of these surveys was to delineate critical pine snake nesting habitat. All potential pine snake nesting habitat was carefully walked by HA staff members parallel to each other and spaced 3 meters apart. Surveys were conducted during the nesting period (late June-early July), as well as in early September.

Five-year Drift Fence Trapping Program

Between 2007 and 2010, one large perimeter drift fence that was approximately 13,000 feet long, in conjunction with 126 snake funnel traps, was erected around 90% of the study site. The drift fence was also operational from April 15, 2006 until October 31, 2006, but was monitored by EcolSciences, Inc. staff and not HA. The fence traversed various habitat types in an attempt to capture free-ranging pine snakes. This technique was used in conjunction with the visual sampling techniques described above to increase the chance of capturing pine snakes (Zappalorti and Torocco 2002).

The perimeter drift fence was also meant to exclude pine snakes and other species from entering the SPR property construction areas. The drift fence was black nylon silt fence, 3-feet in height, and

was supported with wooden oak stakes. Approximately 5 to 8-inches of the fence material was buried below grade level, backfilled and tamped, thereby preventing snakes and other wildlife from crawling under the fence (Enge 1997a and 1997b, Zappalorti and Torocco 2002).

A small hole (approximately 4 inches in diameter) was cut into the fence material at the ground surface, and a box funnel trap was connected to the hole, thus providing a place for snakes and other animals to crawl through the fence and become trapped (Dargan and Stickel 1949; Enge 1997a, 1997b; Casazza et al, 2000).

Each box trap measured approximately three feet long, one foot high and one foot wide. The traps were constructed from treated plywood and 1/4 inch mesh galvanized hardware cloth. Each trap had one plastic funnel placed with its wide end attached to the end of the trap, and the narrow end extending into the trap (**Figure 7**). A hinged lid with latches allowed easy access to trapped snakes (Casazza et al, 2000).

A snake trap works on a principle similar to that of a minnow trap, where fish (and in this case, snakes) are able to enter the trap but have great difficulty in finding their way out. Leaves were placed in each trap to provide a cool, moist retreat for trapped animals. A plywood board was placed over the top to provide shade and reduce exposure to the sun (Enge 1997a and 1997b, 1998a, 1998b and 2001). The 126 traps were removed from the drift fence and the program was terminated as planned at the end of the 2010 field season. The silt fence itself was removed in March of 2011.



Figure 7. An adult male pine snake caught in one of the snake traps along the perimeter drift fence in June 2009. Notice the one-way swinging wire door over the funnel entrance. Photo by Bob Zappalorti, HA.

PROTOCOL FOR RELEASING PINE SNAKES FOUND ON THE SPR PROPERTY

As stated on Page 10 of the June 28, 2006 Memorandum of Agreement, one of the goals of the Species Management Plan was the protection of threatened and endangered species on the SPR property from adverse impacts and direct harm during the redevelopment process. This includes, but is not limited to, the reestablishment of threatened and endangered species at appropriate habitat areas designated by the Pinelands Commission and the NJDEP. Furthermore, the MOA mandates that measures be taken to preclude such species from returning to the disturbed Stafford Park Redevelopment site.

One of the questions in this study addresses whether pine snakes that were shifted in 2006 from the landfill into Stafford Forge WMA would continue to try to access the landfill and development property in the following years, especially females during the nesting season (Burger and Zappalorti 1986 and 1991). Even though HA staff found no pine snakes on the SPR property in 2011, it is important, for data purposes, to allow any pine snakes that choose to enter the landfill or SPR property in the future to move about unmolested, unless they come within close contact with active construction areas. This will continue to be HA's protocol for the remainder of the study.

RADIO-TELEMETRY

Radio-tracking is a method used to monitor the movements, habitat use and behavior of free-ranging pine snakes. Advanced Telemetry Systems, Inc. R1535 or R1520 transmitter units were used. Transmitters were designed so that their mass represents less than 5% of the snake's body weight. The typical reception range of the transmitters was 400 to 1000 meters. Transmitters were surgically implanted in the coelomic cavity following the general procedure of Reinert and Cundall (1982), with improvements and modifications (Mech 1983, Reinert 1992, Lutterschmidt 1994). All snakes captured prior to 2007 were surgically implanted by a veterinarian hired by EcolSciences, Inc. All surgeries performed on snakes captured in 2007, 2008, 2009, 2010 and 2011 were conducted by qualified HA staff members (e.g., Bob Zappalorti, Mike Torocco, Matt McCort and/or Dave Schneider) in HA's laboratory in Jackson, New Jersey.

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

Transmitter Surgeries in 2011

All snake surgeries were completed before August 15, 2011 (Lutterschmidt 1994, Rudolph et al, 1998). Snakes that had their old transmitters replaced in 2009 were again due for new transmitters in 2011. A total of seven pine snakes were pulled from the field for transmitter re-implantation surgery during the 2011 field season. Time frames for snake re-implantation and eventual release varied with the condition of each specimen as HA staff assessed the overall health of each snake. All seven snakes successfully had their old transmitters removed and replaced. In addition to the re-implantation surgeries, a new pine snake (2006.49) was implanted with a one year transmitter.

Activity Range Analysis

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

Minimum Convex Polygon Activity Range

The Minimum Convex Polygon (MCP) method of activity range analysis has historic prominence in the literature due to its relative ease of use. This MCP method uses the outer most points plotted on a map which includes 100% of the relocation points to calculate activity ranges for each snake. The outermost points on the map are connected to form a polygon. The area of the polygon is then calculated to arrive at the MCP activity range. Activity ranges maps were produced using ArcMap 10.0 (Environmental Systems Research Institute, ESRI, Inc., 1999-2010) and activity range maps/calculations were done with XTools Pro for ArcGIS desktop (Copyright 2003-2010 Data East Soft, LLC).

Kernel Activity Range

HA used this additional method to estimate core activity centers of habitat use by the monitored pine snakes. The formula for the Kernel Activity Range is calculated via a fixed range of animal habitat utilization distributed equally within the 50% and 90% isopleth (Worton, 1989). The Kernel method's grid coverage matches the minimum convex polygon and 95% isopleth to determine the smoothing factor (H) (Row and Blouin-Demers, 2006). The bivariate normal density kernel is used as suggested by (Worton 1989). In other words, Kernel Activity Range uses non-parametric statistical procedures to calculate probabilities of an animal being in various locations in two-dimensional space and adjusts the activity range boundaries for local variation in frequency.

Two different measures of activity range were calculated at 90% and 50% respectively. Each percentage is displayed on a base map of the study site as an area, representing the probability (90% and 50%) of each study animal occurring in that area at any given time based on the existing 2011 radio-telemetry data.

Kernel Activity Range was calculated using Geospatial Modeling Environment (GME) (Copyright © 2001-2011 Hawthorne L. Beyer, Ph.D., Spatial Ecology LLC).

RESULTS OF THE 2011 INVESTIGATION

Description of Existing Conditions and Habitats

The 370-acre SPR property consists of a mixture of habitats, comprised mostly of upland pine forest and disturbed open field. The property is bordered to the west and the south by the Division's Stafford Forge Wildlife Management Area and the north and east by Route 72 and the Garden State Parkway, respectively (**Figures 1 and 2**). The northern portion of the property is comprised of three areas: the buffer zone for the Mill Creek wetland corridor, the Ocean County facilities (public works, maintenance, mulching center, etc.), and the capped licensed landfill. A variety of wetland habitats exist within the Mill Creek wetland corridor, such as Atlantic white cedar (*Chamaecyparis thyoides*) swamp, deciduous hardwood swamp, and emergent wetland.

The ecotone or transition area to the upland oak/pine forest, and the oak/pine forest itself, still partially exists and will remain intact, as a good portion is protected within the wetland buffer. The southern portion of the site was formerly a large tract of upland pine forest. This forest was cleared and graded to the property line in 2007. The western portion of the site consists mainly of the licensed, capped landfill and an area temporarily stabilized with vegetation awaiting residential development. Storm water basins and Ocean County municipal property comprise the remainder. The eastern portion of the site is now a new shopping center with chain stores such as Dicks, Best Buy, Pet Smart, Costco and Target. There are two storm water basins and an irrigation pond associated with the shopping mall. The center of the site was cleared and prepared for commercial and residential development in October and November 2008. In 2009, affordable residential housing units were completed on the central portion of the site, opened to the public and are now mostly occupied. In 2011, construction began on the Stafford Park Preserve Luxury Apartments along the southern edge of the SPR property.

Selective Forest Thinning on Hay and Micaja Roads

In addition to the habitat alteration that has occurred on the SPR site, the NJ Forest Fire Service initiated an extensive tree-thinning effort within the Stafford Forge WMA (which borders a majority of the SPR site) during the fall and winter of 2009 - 2010. This was done in response to the major forest fire that raged throughout Stafford Forge WMA in May of 2007. In hopes of reducing damage caused by unexpected forest fires in the future, the fire service began to selectively cut trees within prescribed areas of forest. This forestry procedure is a method used to reduce the risk of accelerated canopy burn during an uncontrolled forest fire (Graham et al 2004). The majority of the forest was essentially cleared of all standing dead or clustered overstory trees approximately 200 meters into the forest from the edge of the sand roads within portions of Stafford Forge WMA. As a result of the clearing operations, large mounds consisting of sandy soil, stumps, logs, brush, sticks and twigs were left behind in the areas where the forest was thinned. This created habitat which can be very beneficial to pine snakes and other wildlife. The open canopy provides essential basking habitat for the snakes while the stump, log and earth mounds provide needed cover and shelter during the course of their activity season (Friar and Zappalorti 1983). The open forest also attracts a variety of small mammal and bird species which provide important prey items for the snakes. Indeed, a few of the study snakes were relocated using the areas that had been thinned by the forest service on a regular basis during the 2011 field season (refer to Snake Synopses and Home Range Maps).

REPTILE AND AMPHIBIAN SURVEYS

Visual Survey Results

In 2011, random searching and visual surveys resulted in the observation, capture and identification of 19 different reptile and amphibian species in and around the SPR property and the adjacent Stafford Forge WMA. **Table 2** lists the 19 assorted species captured or observed during the 2011 field season. Several reptile and amphibian species were found while conducting radio-tracking monitoring of pine snakes, such as black racer, hognose snake, and Fowler's toad (**Figures 8, 9 and 10**).

Table 2. Reptile and Amphibian Species Captured or Observed in and around the SPR Property and the adjacent Stafford Forge WMA in 2011.

Number of Species	Common Name	Scientific Name
1	Eastern Box Turtle	<i>(Terrapene c. carolina)</i>
2	Eastern Painted Turtle	<i>(Chrysemys p. picta)</i>
3	Redbelly Turtle	<i>(Pseudemys rubriventris)</i>
4	Northern Fence Lizard	<i>(Sceloporus undulatus hyacinthinus)</i>
5	Northern Water Snake	<i>(Nerodia s. sipedon)</i>
6	Eastern Garter Snake	<i>(Thamnophis s. sirtalis)</i>
7	Eastern Ribbon Snake	<i>(Thamnophis s. sauritus)</i>
8	Southern Ringneck Snake	<i>(Diadophis punctatus)</i>
9	Rough Green Snake	<i>(Opheodrys aestivus)</i>
10	Eastern Hognose Snake*	<i>(Heterodon platirhinos)</i>
11	Northern Black Racer*	<i>(Coluber c. constrictor)</i>
12	Northern Pine Snake*	<i>(Pituophis m. melanoleucus)</i>
13	Fowler's Toad*	<i>(Anaxyrus fowleri)</i>
14	Northern Spring Peeper (Vocalizing)	<i>(Pseudacris c. crucifer)</i>
15	Pine Barrens Treefrog (Vocalizing)	<i>(Hyla andersonii)</i>
16	Southern Gray Treefrog (Vocalizing)*	<i>(Hyla chrysoscelis)</i>
17	Southern Leopard Frog	<i>(Lithobates sphenoccephalus)</i>
18	Green Frog	<i>(Lithobates clamitans melanota)</i>
19	Bullfrog	<i>(Lithobates catesbeiana)</i>

Note: * = These various species of reptiles and amphibians are illustrated in this report.



Figure 8. A hatchling northern black racer. Bob Hamilton, HA.



Figure 9. A defensive hognose snake gapping its mouth open. Photo by Bob Hamilton, HA.



Figure 10. A Fowler's toad, one of the most common amphibians at the study area. These toads are the favorite prey item of the eastern hognose snake. Photo by Bob Hamilton, HA.



Figure 11. An adult female pine snake crawling into an abandoned fox burrow, that was used as a communal hibernaculum. Large mammal burrows were the most frequently used winter refugia for hibernation by pine snakes in the Stafford Forge WMA. Photo by Bob Zappalorti, HA.

ARTIFICIAL AND NATURAL DENS

As a result of our intensive radio-tracking studies, HA discovered a large number of natural pine snake dens over the past five field seasons (**Figure 11**). HA's definition of a "Natural Hibernacula," is any underground structure in the forest that a free roaming pine snake selected as its winter refugia. In 2011, five new natural dens were discovered. In order to prevent confusion, all artificial dens in the management fields are referred to as "Artificial Hibernacula" (AH 1 through 6). Whereas, all natural dens are designated as "Natural Hibernacula" (NH 1 through NH 45). **Appendix I** shows each individually designated hibernacula and the corresponding snakes that utilized them during each winter of the study. The 2007-2008 winter was the last winter that snakes were forcefully held within the two-winter treatments (AH 1, AH 4, and AH 6), completing the experimental habitat imprinting portion of the study. Therefore, all overwintering sites used by radio-tracked snakes in the 2011-2012 winter season were selected by the snakes, without any influence from HA researchers.

RESULTS OF RADIO-TRACKING

In 2011, a total of 14 pine snakes were radio-tracked during the active field season (April through October). These include 6 original "shifted snakes," 7 "non-shifted" snakes, and one newly captured 2006 hatchling. Of the six shifted pine snakes tracked by HA at the start of 2011, four snakes (3 males and 1 female) remain alive and healthy, one is presumed deceased (female pine snake 2006.29) and one (male pine snake 2006.08) is currently missing. All of the seven non-shifted snakes (5 males and 2 females) radio-tracked in 2011 are alive and healthy. The 2006 hatchling (2006.49) is also alive and healthy (refer to Snake Synopses and Home Range Maps).

SNAKE SYNOPSES AND HOME RANGE MAPS

ABOUT THE HOME RANGE MAPS

The Endangered and Nongame Species Program reviewed and approved the pine snake's activity range maps that are provided in this report. These pine snake home range maps were generated by collecting relocation GPS coordinates while radio-tracking. Each base map shows the land boundaries of the SPR property, the Department's Stafford Forge Wildlife Management Area, along with plotted GPS snake relocation points. The activity/home



Figure 12. Female 2006.08, was found crawling across Hay Road on May 3, 2011. When Bob Hamilton stopped to photograph the snake, it crawled to the nearest pitch pine, and climbed up into the tree demonstrating predator avoidance.

range information is shown graphically by plotting the land area used by each radio-tracked pine snake. Two methods were used to arrive at the activity range size for each snake: 100% Minimum Convex Polygon and Kernel Activity Range (Samuel et al, 1985; Tiebout and Carey 1987; Tufto et al, 1996; Seaman and Powell 1996, Hooge et al. 1997, USGS, Alaska Biological Science Center).

SNAKE SYNOPSES

A brief synopsis of every adult pine snake involved in the radio-telemetry aspect of this project during the 2011 field season, whether currently alive or deceased, is detailed below. **Appendix II** in the back of this report provides a brief synopsis of each snake that died, prior to the 2011 radio-telemetry season. Additionally, home range analysis maps of the radio-tracked pine snake relocations in 2011 (the combined movements and sizes), during their activity season are also provided. These maps are included within the synopsis for each snake. Please refer to the maps for information on each individual pine snake's activity range size during the 2011 field season.

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

On 04/21/2011 this snake egressed from NH 2. It was relocated 73 times during the 2011 field season. Similar to prior field seasons, this snake occupied the habitat between MF 3 and Route 72 to the north. However, this snake spent more time in the Mill Creek wetland corridor and the pine/oak forest north of the wetland than in previous field seasons. For the first few weeks of the activity season, this snake was relocated in a mound along the outer corral path of MF3 and in the adjacent pine forest. On 05/03/2011, it was found crossing Hay Road, heading north. Interestingly, once across the road, the snake scaled the nearest pitch pine tree instead of continuing on into the undergrowth (**Figures 13 and 14**).



Figure 13. Female pine snake 2006.08, climbed up a pitch pine tree as a predator avoidance response when confronted on an open sand road. Tree climbing has been observed several times by HA in the past, especially by pine snakes at a study site in Cumberland County, New Jersey. Both photos by Bob Hamilton, HA Staff.

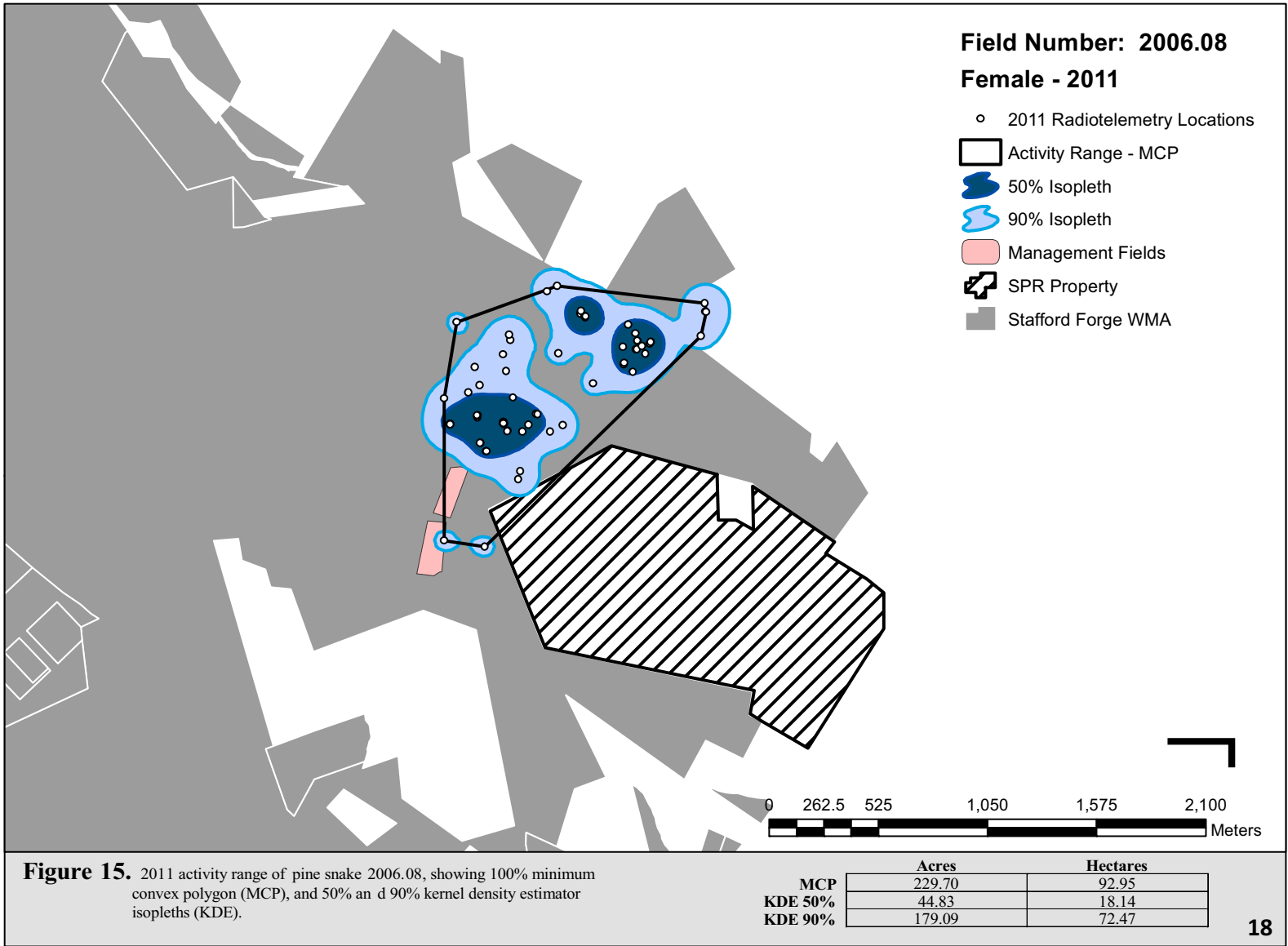
After crossing Hay Road, this study snake divided its time between the Mill Creek wetland habitat and the upland forest to the north of the wetland corridor. Often times, it was relocated in a section of severely burned wetland habitat characterized by large, widely separated standing dead Atlantic white cedar (*Chamaecyparis thyoides*), and a dense shrub layer dominated by dwarf huckleberry (*Gaylussacia dumosa*). This area was frequented by the deceased study snake 2007.04 in the past, and also by this snake in 2010. It's possible that this transitional forest area satisfies a multitude of this snake's biological needs simultaneously (e.g., foraging, ground cover, thermoregulation and hydration).

Throughout the activity season this snake would intermittently return to the vicinity of the management fields and was found multiple times concealed in the berms. It is highly likely that the snake uses the berms as a safe place to bask and hide during its shedding cycle, a behavior noted



Figure 14. A close-up shot of 2006.08, resting in a pitch pine tree.

with other radio-tracked pine snakes throughout the study. Following a relocation on 10/28/2011, HA staff was unable to pick up this snake's transmitter signal. It is possible that the snake was predated on, or possibly, the transmitter failed for some reason. In the spring, HA will corral NH 2 (the den this snake has used every winter) in case the transmitter had indeed failed and the snake returned to its den. If the snake is not recaptured at the den in the spring, HA staff will continue its search efforts throughout the 2012 activity season in the unlikely event that this snake's transmitter is functioning. It is possible that it somehow managed to evade location by moving to a previously unknown den.



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

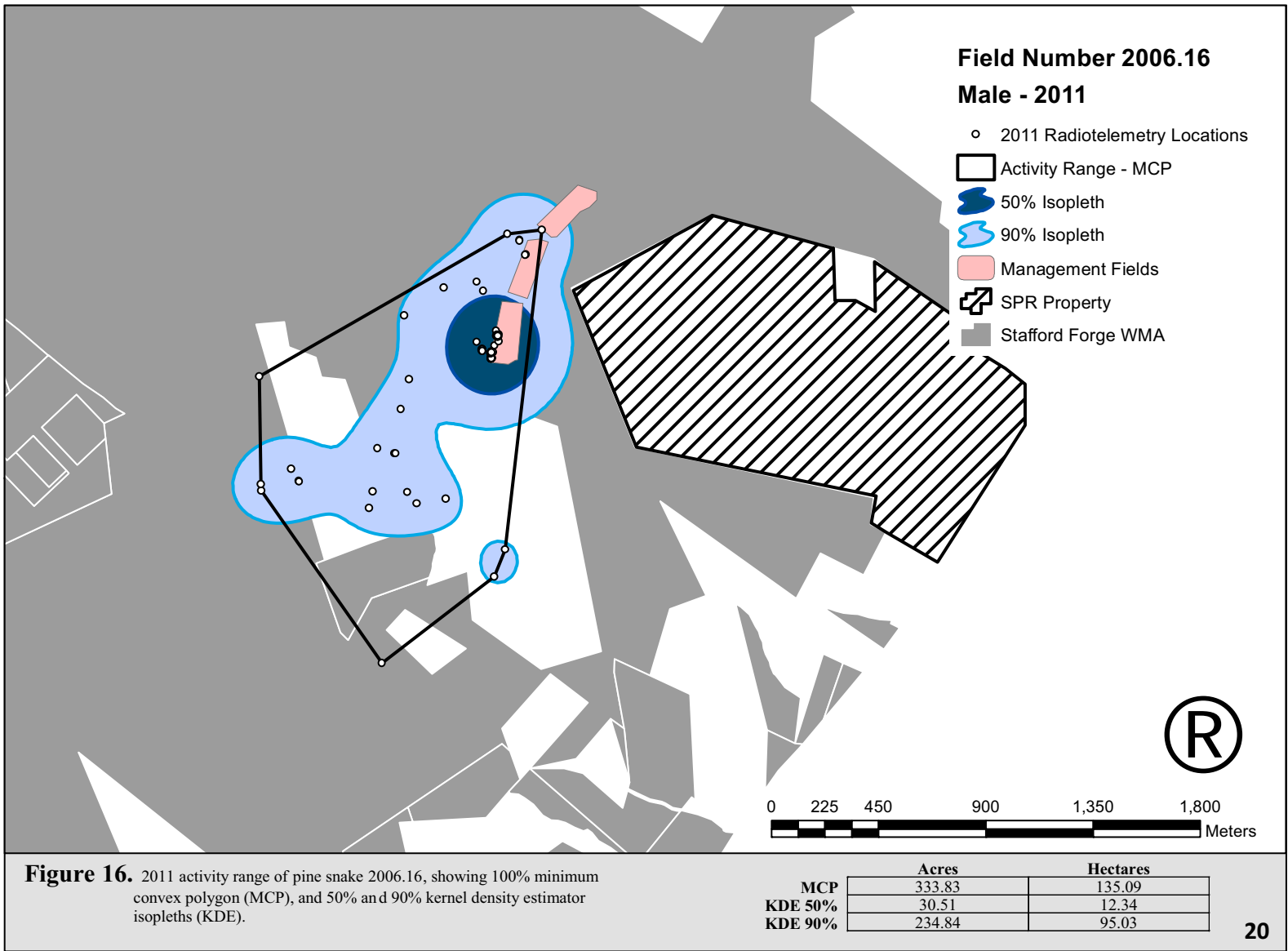
This snake was found in a trap attached to AH 1 on 05/03/2011 and released. It was relocated 104 times during the 2011 field season. For the majority of the month of May this snake was found near the management fields, either concealed in the earth berms that surround the fields, or under vegetation along the edges of the berms. However, on a few occasions during May the snake was relocated in a section of pine/oak forest approximately 850-meters southwest of MF 1. This habitat was identified as part of the snake's home range in prior field seasons.

On 06/09/2011, this snake moved into the berm along the southwest edge of MF 1 and remained there for a period of approximately one week. This location in the management field berm has been used by this snake in prior field seasons and was thought to be a probable shedding station. Throughout the active field season this snake was concealed in the berm at this location for extended periods of time. Even though the snake was never observed while concealed in the berm, it is highly likely the snake was opaque during these periods. Both the amount of time the snake spends in the berm and the appearance of the snake when it finally emerges (its coloration is much more vibrant), allude to this possibility. Upon leaving the berm on 06/17/2011, this snake was consistently relocated for the remainder of June in the pine/oak forest southwest of management field one, as previously mentioned above. During this period the snake was often observed foraging, and on one occasion a large bulge was noted in the snake's stomach confirming that it had recently taken a meal.

On 07/06/2011, this male snake again moved into the berm along MF 1, where it had been at the beginning of June. The snake remained in the berm for the first half of July. For the remainder of July and the first half of August this snake was consistently relocated in the same pine/oak forest as previously mentioned. During the hotter periods of the day it was often relocated underground or concealed amongst the understory shrub and duff layer. The snake was observed moving during the early morning hours when temperatures were cooler. On one occasion during July, this snake made a foray into the Cedar Run wetland corridor located approximately one kilometer southwest of the management fields where it was found concealed amongst the root systems of a highbush blueberry (*Vaccinium corymbosum*) shrub.

Then on 08/10/2011, this snake moved back into the earth berm along the southwest side of MF 1 and remained concealed in there for 35 days. It was not seen outside of the berm again until 09/14/2011, when it was relocated in a small mammal burrow in the pine forest approximately 50 meters west of MF 1. It remained at this location for the rest of September and was only observed once above ground when it was found basking near the entrance to the burrow. This snake was never observed feeding during the 2011 field season, however its numerous relocations in the berms (also suitable habitat for rodents) and small mammal burrows, along with its healthy body weight throughout the summer, suggests it found plenty of prey items.

On 10/01/2011, it had finally emerged from the burrow and was relocated in or near MF 2 for the next two weeks. On 10/17/2011, it entered AH 1 where it is currently overwintering. This snake has overwintered in AH 1 for the past 5-years of this study.



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

This snake emerged from AH 1 on 04/25/2011. It was relocated 104 times during the 2011 activity season. As in prior field seasons, this snake was the snake that was most often relocated near the management fields. From the time it egressed on the 25th of April until 05/22/2011, this snake never ventured more than 50 meters away from the edges of the management fields. A majority of the relocations during this period found the snake partially concealed under leaf litter in the pine forest that borders the western edge of the fields. It was also recorded in the earth mounds that line the outer corral path of AH 1. These mounds consist of pine logs and sand and were created during the clearing of the corral paths. In prior field seasons this snake was found in or near these earth mounds when it was going through its shed cycle. This was again the case during the 2011 field season. On 05/15/2011 it was seen opaque while basking within a few meters of one of the earth mounds. It remained in or near this earth mound for the next week as it completed the shedding process.

After shedding, this snake began to move towards the southwest away from the management fields, eventually making its way to the pine/oak forest near the landmark known as “The Turtle Pond” (refer to **Appendix IV** for frequently referenced landmarks). It only remained in this area for a few days before returning to the vicinity of the management fields.

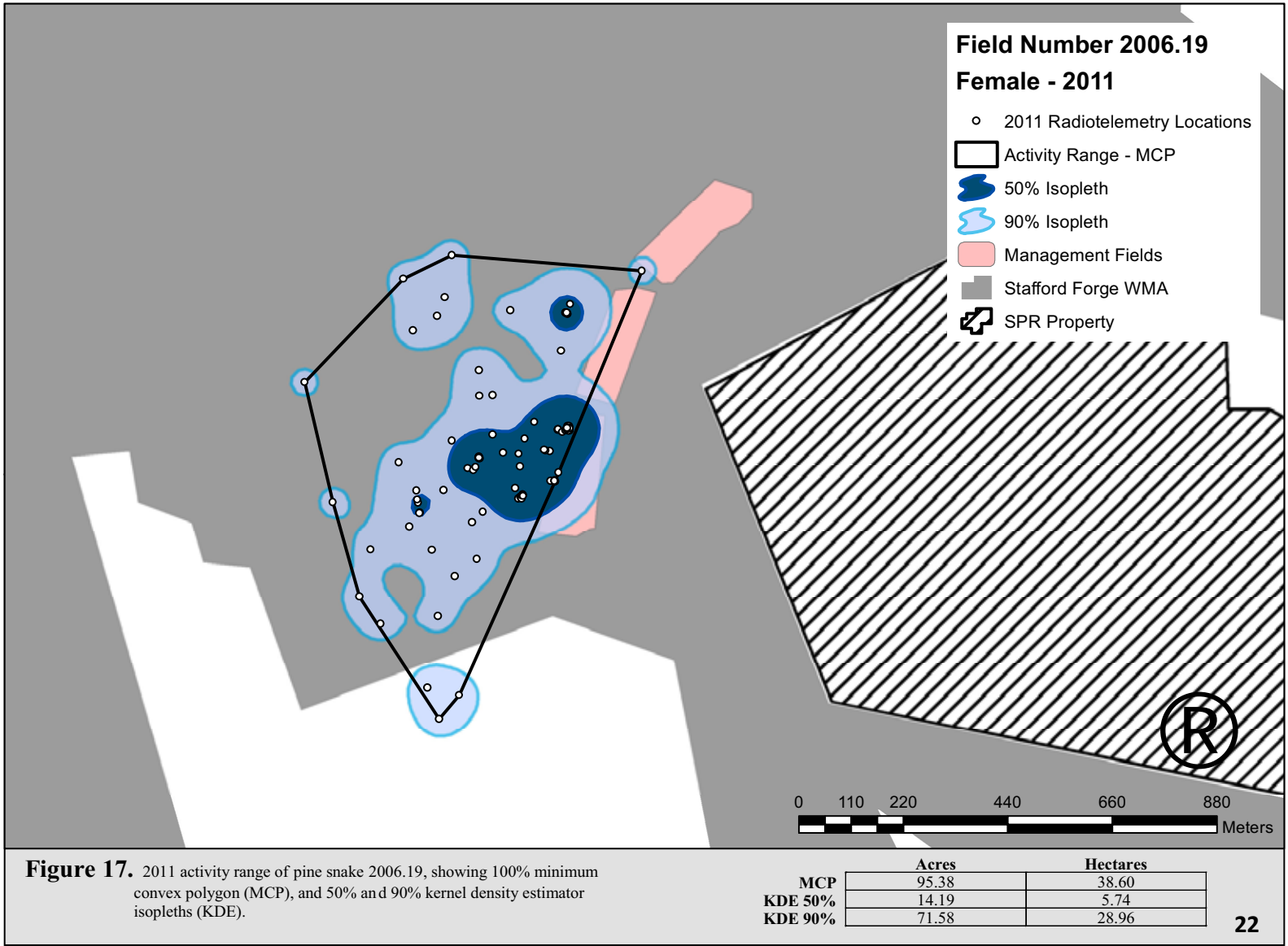
During the first month and a half of the activity season (breeding season) this female was never observed mating. The fact that it was never recorded nesting during the month of June either, highly suggests this snake never became gravid.

During the middle of June this snake was once again relocated in and around the earth mounds lining the outer corral path of AH 1. Then on 06/21/2011, it was relocated in pine/oak forest approximately 650 meters southwest of the management fields. This is an area of forest that study snake 2006.16 is often located in. This was the furthest this snake has ever been recorded from the management fields.

For the remainder of the activity season this snake was consistently relocated splitting its time between the habitat immediately surrounding the management fields and the pine forest and pine/oak forest southwest of the management fields.

Although, this snake always appeared to maintain a healthy body weight it was never observed feeding on a prey item during the 2011 field season.

On 10/17/2011, this snake entered AH 2 where it is currently overwintering. It is interesting to note that during every prior winter this snake overwintered in AH 1 along with study snake 2006.16. It is unknown why this snake chose to spend this winter in AH 2 instead of AH 1.



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

Last winter on 10/08/10, this snake had reached NH 20, a den it had used in previous years. Over the next several relocations, the snake was found both inside the den, and basking in very close proximity to it. Then on 10/30/10, the pine snake moved approximately 200-meters southeast to a very large mammal burrow. It was not clear why the snake chose to abandon its previously successful hibernaculum in favor of a new one.

For poorly understood reasons, this adult female pine snake failed to emerge from its winter hibernation site in the spring of 2011. HA continually checked on the snake's transmitter signal throughout the spring and summer months, and the radio signal always indicated that the snake was still in the den. Normally, HA staff will attempt to dig up a snake when the transmitter indicates it has not egressed from a den location. However, the location along with the den size and structure (large mammal burrow with thick vegetation surrounding it) made it impossible to excavate the den in this case.

Because this pine snake never came to the surface over the entire summer season, the snake was presumed dead. It's not unusual for pine snakes to die while in hibernation. Burger et al. (1992), identified several mammal predators that invade snake dens during the winter and attack and kill them while they are cold and dormant (short-tailed shrew, red squirrel or skunk).



Figure 18. An adult male study snake found crossing Hay Road. Photo by Bob Hamilton, HA Staff.

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

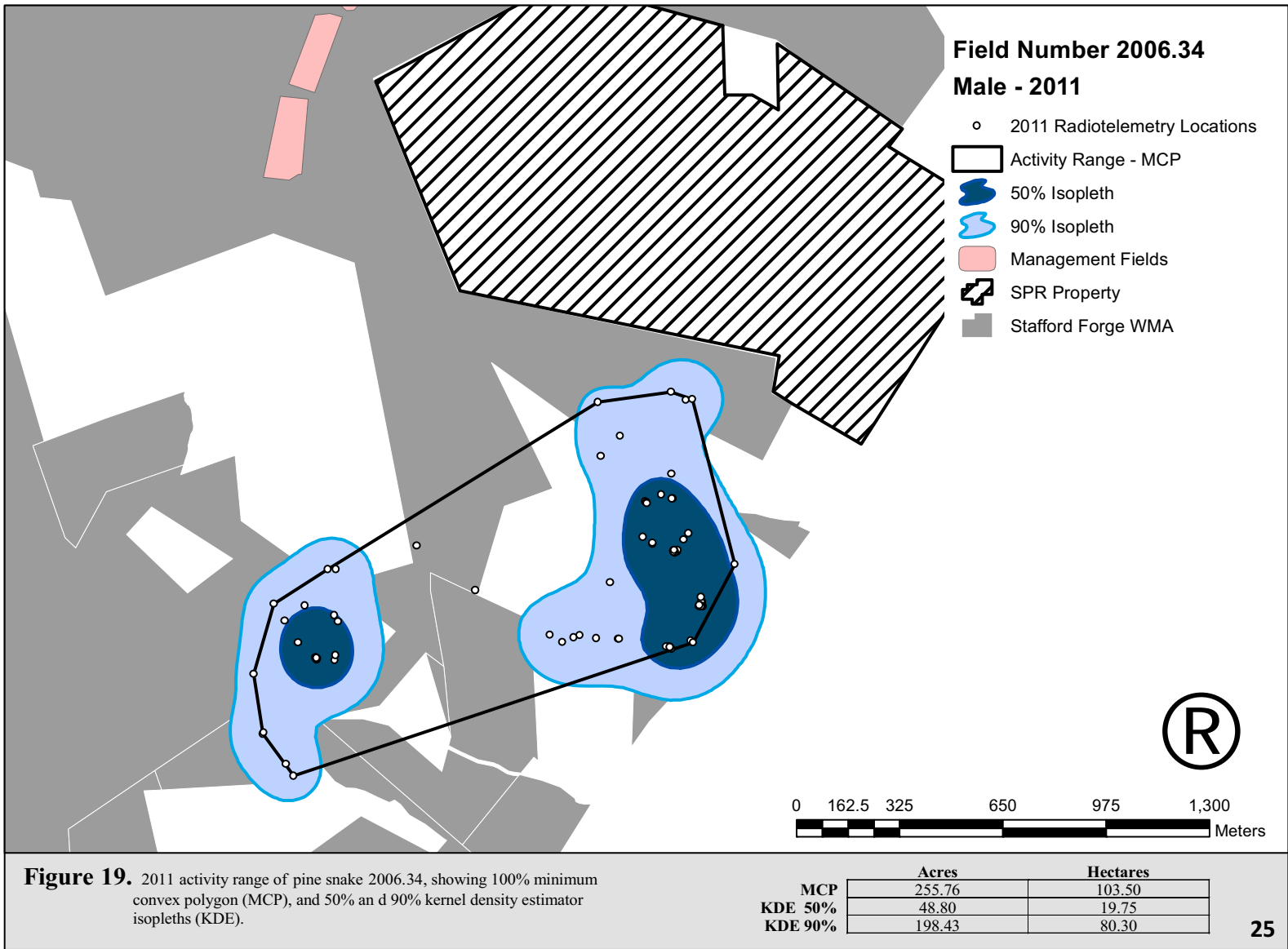
This snake had already egressed from its den prior to the commencement of radio-tracking activities on 04/15/2011. It was relocated 96 times during the 2011 field season. At the beginning of the activity period this snake made a series of small moves in an area of oak/pine forest located over 1.5 kilometers southeast of the management fields. This area of forest borders the edge of the Garden State Parkway. This section of the Stafford Forge Wildlife Management Area forest has been used by this snake in prior field seasons especially in the early portion of the season. This is an area where this snake is usually observed mating on multiple occasions during the breeding season. However, this year it was not observed mating. One reason for this may be that one of the female snakes that this male would breed with in prior field seasons was study snake 2007.05 which went missing last field season. It is possible that this male often mated with this female due to their home ranges overlapping and if she was predated on last year, study snake 2006.34 may not have come in contact with any other females during the breeding season this year.

On 4/27/2011 this snake was relocated beneath or inside a rubber tire on the landmark known as “The Glass Pile” (refer to **Appendix IV** for frequently referenced landmarks). This snake is relocated here every year and is oftentimes in a pre-shed condition when found. However, on this occasion the snake was not opaque since it only spent two days in the tire and then moved off into the Cedar Run wetland corridor that bisects the forest south of the construction site. Every season this snake is relocated within this wetland corridor on multiple occasions and seems to be one of a handful of snakes that are relocated in wetland habitat more often than other study snakes. It's possible that the snake is moving into the wetland due to a greater availability of prey.

After spending approximately one week in the wetland this snake made a large move back towards the northeast into the pine/oak forest near the Costco store. When it was relocated on 05/13/2011, it looked as though the snake may have recently fed due to a large bolus observed in the snake's mid-section. It remained in this area for the next two weeks before moving back to the vicinity of “The Glass Pile.”

This snake spent the majority of June and the beginning of July concealed either under or in the rubber tire on “The Glass Pile” where it was earlier in the season. It was only observed outside of the tire on a few locations and it was never more than a few meters from the tire. It's quite likely this snake was going through a shed cycle during this period of time, as well as, possibly becoming less active due to higher temperatures during this part of the summer. After returning once again to the Cedar Run wetland corridor in late July, the snake moved back to the north/northeast into the pine/oak forest nearer to Costco. During this period of time the snake was often concealed amongst the shrub layer and duff layer or underground trying to avoid the oppressive heat.

On 08/12/2011 this snake moved into a moderate sized mammal burrow that had been excavated under a large slab of rock on a small rise in pine/oak forest near the Garden State Parkway. It remained in or within a few meters of the mammal burrow for almost a month, finally moving away from the burrow on 09/07/2011. For the remainder of September and beginning of October this snake made small moves in the pine/oak forest southwest of Costco. Often times during this period the snake was observed in stump holes. On 10/13/2011 it was found in a stump hole where there are two very old relocation flags. This is where the snake is currently overwintering.



N. Pine Snake 2006.49 (♂). (2006 Hatchling, Treatment A/1 Winter) Current status = Alive and healthy. This snake was originally hatched out in HA's lab in 2006 and released into AH 1.

This snake was found in a trap attached to AH 1 at the end of May. It was implanted with a one year transmitter and released outside the den. It was relocated 56 times during the 2011 field season. This snake was one of the 2006 hatchlings that were hatched out in the HA lab and released into the artificial dens in the fall of 2006. It had been recaptured by HA staff during the 2008 and 2009 field seasons, but had been too small to implant with a transmitter in both instances. It had also been recorded overwintering at AH 1 during the 2008/09 winter.

Upon its release, this snake immediately moved southeast, away from the management fields, and was relocated in a pine/oak forest nearly a kilometer from where it was released following the surgery. At this time, the snake was observed to be in a pre-shed condition, which often occurs following transmitter surgeries. The snake spent the next two weeks in the same general area spending most of the time concealed amongst the shrub and duff layers.

On 07/04/2011, it had moved north from the pine/oak forest into a dense pine forest just north of Slocum Road. The snake spent the majority of July and early August in this dense pine forest and, as was the case with most of the snakes, was observed traveling when located during cooler morning hour. It was observed seeking shelter amongst the shrub layer or underground during the hotter afternoon hours. It is interesting to note that during this time HA staff continually had trouble with this snake's signal. When HA staff were able to finally pick up the signal, it was usually extremely weak until the observer was within a few meters of the snake. It is unknown whether the terrain had anything to do with the signal problems.

On 08/18/2011, this snake was found in an earth mound that was created when the developers cleared a small road through the woods along the south side of the construction area. For the remainder of August, it was either relocated in, or next to, this earth mound or under a scrub oak (*Quercus ilicifolia*) situated alongside a small dirt trail, not far from the edge of the landfill.

On 09/14/2011, an HA staff member tracked this snake into a portion of upland pine/oak forest a few hundred meters south of the construction area. On this occasion, the snake had originally been observed traveling along the forest floor, however, as the observer was setting up to collect climatic and GPS data he noticed a white-footed mouse (*Peromyscus leucopus*) scurry by with three baby mice clinging to the mouse's back. The observer decided to locate the snake again to see if it was pursuing this fleeing mouse. When the snake was found (a span of approximately four minutes from the initial observation) it was observed constricting and then consuming an adult white-footed mouse. However, this mouse was in the opposite direction of the mouse observed running away. The snake must have raided a nest that possibly had two adults in it at the time and was able to kill one while the other escaped with the babies. It then spent the next week in the same general area of forest.

In late September this snake moved back towards the management fields and was relocated in one of the large brush piles in the middle of MF 1 on 09/30/2011. HA staff expected this snake to move back into AH 1 to overwinter, however, the snake actually moved out of the management fields and into pine forest 100 meters south of the management field's access road. On 10/07/2011 it was relocated in a moderate sized mammal burrow in this section of pine forest and is currently overwintering there. This is a previously unknown den site.

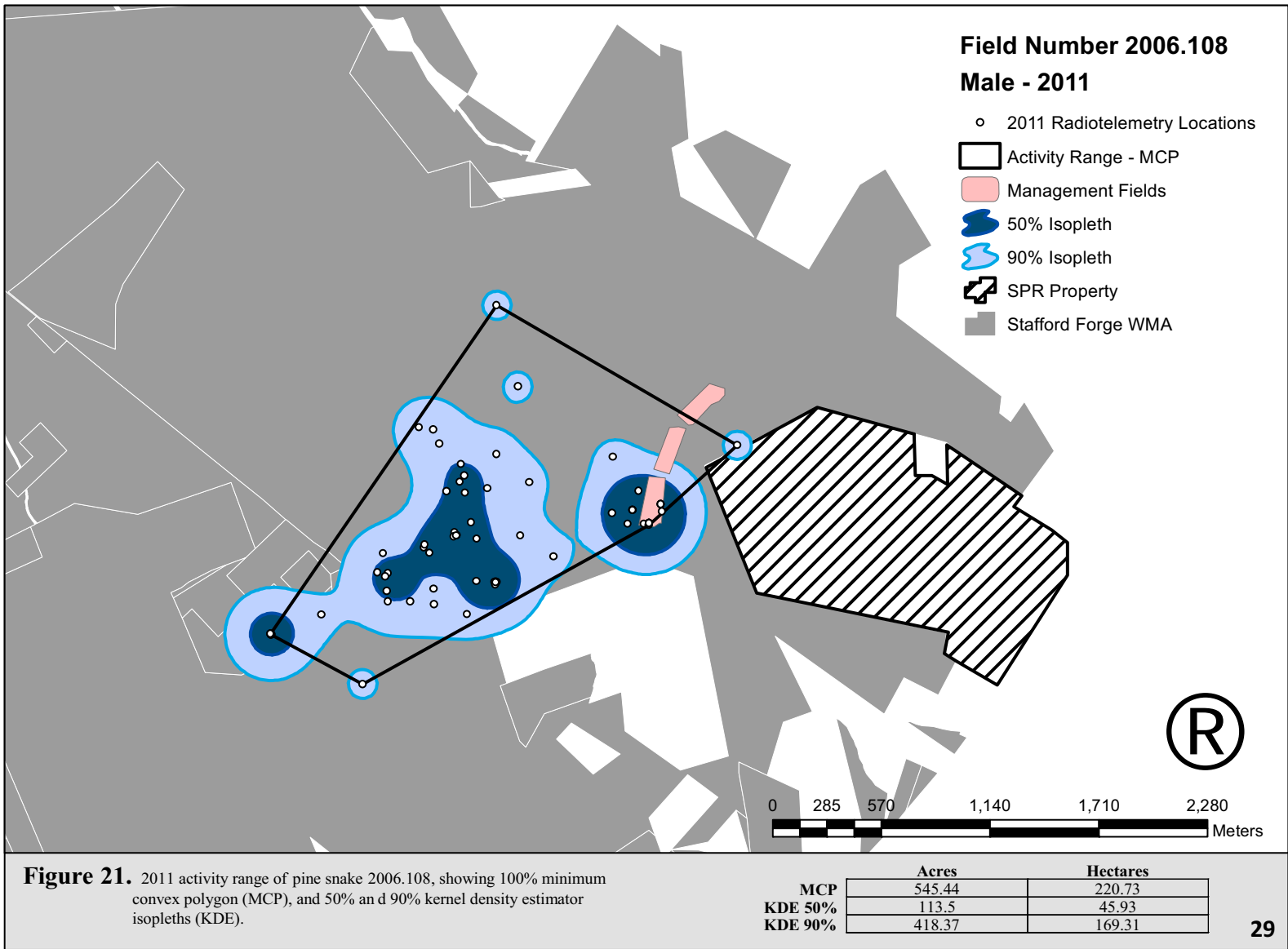
N. Pine Snake No. 2006.108 (♂) (Shifted Snake, Treatment A/1 winter) Current status = Alive and healthy. This snake was originally caught in trap 10 of the perimeter drift fence by EcolSciences, Inc. on 10/05/06.

This snake egressed from its den on 04/19/2011 and was relocated 77 times during the 2011 field season. It spent the first few days of the activity season near the den, often times being found basking within a few meters of the den opening. When it was relocated on 04/23/2011, it had made a move of over 1.1 kilometers southeast to the management fields and remained in the general vicinity of the fields for the remainder of April. This snake was found in and around the management fields on multiple occasions during the 2010 field season as well.

On 05/03/2011, this snake made another large move of approximately 1 kilometer into the pine forest northeast of the management fields and was relocated underground in a small mammal burrow. HA staff relocated study snakes at this burrow in prior field seasons. Each time a snake is found at this burrow there is evidence indicating small mammal activity in the area. This evidence is mainly in the form of discarded pine chips/axes from small mammals feeding on pitch pine cones. For the remainder of May this snake made consistently large moves within 48 and even 24 hour time periods. Often times these moves between relocations were over 1 kilometer. The snake would move from the area of the management fields and either into the upland pine forest directly west and northwest of the fields or into the pine/oak forest southwest of the fields. This is all habitat that was recognized as part of the snake's home range through radio-tracking efforts in 2010. On 05/26/2011 the snake was pulled from the field to have its transmitter replaced.

Upon release into the management fields following transmitter surgery, this snake immediately made a large move to the southwest into upland pine/oak forest previously established as part of this snake's home range. This is an area in which study snake 2006.16 is often found. Following a few moderate sized moves within this tract of forest, when the snake often appeared to be foraging, it went into shed beneath a fallen log where it remained for approximately one week. During this time period, HA staff noted that the snake appeared rather thin. The large moves this snake was making during the month of May possibly reflects the difficulty it was having in finding food. Following its shed cycle the snake again made a large move into a dense upland pine forest west of Micaja Road. This was an area the snake had never previously been recorded in. After a couple days in this pine forest it made a large move back to the pine/oak forest east of Micaja Road. Once again, these large moves may be a reflection of the snake having trouble finding prey items. As with most of the snakes during this time, it was often recorded moving in the early morning hours and concealed or underground in the hotter afternoon hours. It then returned to the same log it had been under approximately one month earlier and once again went into shed.

In the middle of August this snake moved back to the management fields and entered the earth berm in the southwest corner of MF 1 where study snake 2006.16 is consistently recorded at during the activity season. It remained there till the end of August. In early September, it left the berm and moved almost 1.8 kilometers into upland pine forest west of Micaja Road. Once again, this was an area of forest this snake had never been recorded in before and it still appeared to have low body weight. At this point the snake disappeared and despite repeated efforts by HA staff was not found again until 10/31/2011 when it was located at a previously known natural den where it is currently overwintering. It is possible that this snake was having so much trouble finding prey during the late field season it had moved into an area that was not accessible to HA staff, before turning up at the den.



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

This snake egressed from NH 28 on 04/21/2011. It was relocated 71 times during the 2011 field season. By 05/05/2011, this snake had moved north away from its den, crossing Hay Road in the process. On 05/09/2011, it was observed consuming a nest of young eastern cottontail rabbits in the pine forest just north of the road (**Figure 22**). The snake then spent the remainder of the season in an area of disturbed forest between the Mill Creek wetland corridor and Route 72. It was often found in a sparsely canopied pine/oak forest that contained a dense layer of undergrowth vegetation. During this time it was often observed foraging along the forest floor.

Beginning on 07/18/2011, this snake was consistently located underground in a stump hole for a two week period. When it finally emerged from the stump hole it appeared to have gone through a shed cycle. Unlike a few of the other study snakes, this snake does not seem to have an affinity for any one particular "shedding station". After coming out of shed, this snake was often observed traveling and foraging through the same pine/oak forest it was observed in prior to its shed cycle.

On 08/02/2011, this snake was relocated concealed under vegetation within very close proximity to Route 72. It was also noted at this location during the 2010 field season. At this time it was collected for transmitter surgery and released back into the field on 08/18/2011.

Following transmitter surgery, this snake spent the majority of the remainder of the 2011 activity season in an area of disturbed forest near "The Power Cut" (refer to **Appendix IV** for frequently referenced landmarks). In early October it returned to within 15m of where it was found on 08/02/2011. It remained in this location for several days before moving south to a previously known den (NH 33) where it is currently overwintering.



Figure 22. Female pine snake 2007.07, constricting and eating nestling cottontail rabbits that she located in a ground nest. She ate all four rabbits in the nest. Photo by Bob Hamilton, HA Staff.

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

This snake egressed from NH 39 on 04/19/2011. This snake spent the beginning of the activity season in pine dominated forest south of its hibernaculum. This is a section of forest that is quite remote relative to other portions of Stafford Forge WMA and has extremely poor road access. From late April until the beginning of June, this snake made small moves, consistently heading south away from its den. The terrain of the habitat it was using at this time (upland pine forest with undulating topography) was not conducive to long-range radio-transmission signal. This resulted in several periods of poor reception and at times, total signal absence.

On 06/02/2011, this snake was relocated near Grays Road, having moved approximately 2.3 km southwest of its den site since egress. The snake then crossed Grays Road into an upland pine dominated pine/oak forest, south and west of the road. This forest has been identified as part of this snake's home range in prior field seasons. During this time, it was frequently found at the same locations it used in previous activity seasons. One such location, an old buried rubber tire, was revisited by this snake multiple times in 2011, and has been recorded as an important "shedding station" for this snake. It was also found under a discarded metal door on multiple occasions.

On 07/29/2011, this snake was collected for transmitter surgery. After surgery, the snake spent the majority of the remainder of the field season in the upland pine forest immediately north of Gray's Road. It remained in this area until late in the season, when it moved into the more remote section of forest towards its winter hibernaculum, resulting in a loss of signal. This snake's signal was re-acquired on 10/15/2011 when it was located back in NH 39, where it is currently overwintering.

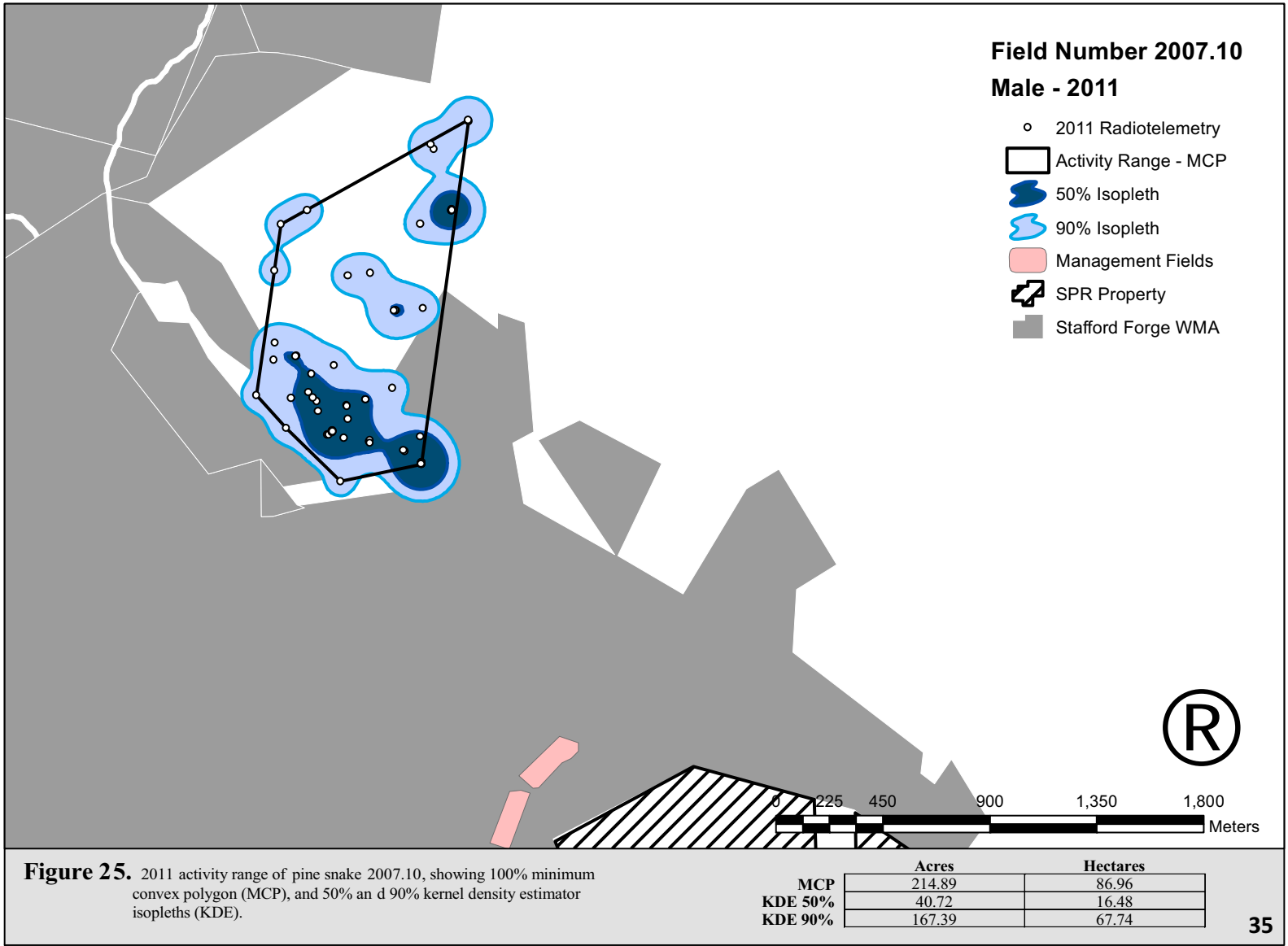
N. Pine Snake No. 2007.10 (♂). Current status = Alive and healthy. This snake was originally captured by HA staff on 06/05/07 traveling near the radio tower along the northern portion of the SPR construction site.

This snake had emerged from its winter hibernaculum (NH 31) by 04/17/2011, when it was found basking near the den opening. It was relocated 84 times during the 2011 field season. By 04/21/2011 it had made a significant move away from its den. It was concealed inside a hollow log that it had been recorded in during prior field seasons.

On 04/27/2011, this study snake was found feeding on a nest of young eastern cottontail rabbits. During 2011, this snake was routinely located in habitat previously identified as its home range. This habitat is a large expanse of pine/oak and oak/pine forest situated between the Mill Creek wetland corridor and Route 72. Often times, it was located in fallen logs and stump holes where relocation flags for this snake from prior field seasons had been placed.

In previous years, this snake has been noted moving "outside" its typical home range with the perceived intention of mating with female study snake 2006.29. However, in 2011, this snake never made an attempt to move south across the Mill Creek corridor. On 05/05/2011 this snake was located in close proximity to female study snake 2007.07. These two snakes have mated in the past, however on this occasion, no courtship was observed between them and female study snake 2007.07 was never observed gravid in 2011 indicating that they most likely did not mate.

On 10/14/2011, this snake was located underground in what would eventually be designated as NH 43. This previously unrecorded hibernaculum is 420 meters northeast of the nearest den in which this snake has been recorded. This location is one kilometer north of NH 31 (which it used the previous winter). The underground structure does not have an obvious entrance and is likely a root system or small mammal burrow.



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

This snake was captured in a trap attached to the NH 8 corral on 04/20/2011 and immediately released outside the corral wall. It was relocated 93 times during the 2011 field season. This snake once again used a large section of habitat comprised of upland pine forest, disturbed pine forest, pine/oak forest and forested wetland habitat ranging south/southwest of the management fields. This area includes the large disturbed section of pine forest known as the “Stafford Triangle”(refer to **Appendices IV** for frequently referenced landmarks).

During the first two months of the activity season this snake continuously made moderate to large sized moves between these different habitats. Often times it was found in close proximity to several dirt roads that bisect the far southwestern portion of the study site and would cross them on a regular basis. The snake was often found traveling and foraging, but was never observed actually feeding. However, the snake always displayed robust body weight, so, it is likely the snake had no trouble finding enough prey. Also, this snake was never observed mating during this time period which encompassed the breeding season.

On 06/11/2011, this snake moved into an area of pine forest between Old Country Road and the Garden State Parkway that it had never been found in during prior field seasons. It remained in this area for the next week and a half as it went through a shed cycle. After coming out of shed, this snake was recorded actively foraging in a small segment of forested wetland before moving into a moderate sized mammal burrow. This burrow displayed fresh signs of small mammal activity. There was a large amount of discarded pine chips/axes indicating a small mammal had been feeding on pine cones at this location. There were also old relocation flags for this snake at the burrow identifying it as a spot it had been to in prior field seasons. In fact, this snake was found numerous times next to or very near old relocation flags from previous years throughout the entire 2011 field season. For the remainder of June and July this snake moved within the confines of its home range established during prior radio-tracking seasons. Often times it was found in medium to large sized mammal burrows escaping the heat of the summer days.

At the beginning of August this snake was relocated concealed amongst a pile of tin and pine needles in the “Stafford Triangle”. It had been at this location on one occasion at the very beginning of the field season and was also recorded at this tin pile towards the end of the 2010 season. This snake remained concealed amongst the tin for the first half of August. During this time period another pine snake was routinely observed basking or concealed under the shrub layer less than a meter from the tin pile. This non-radio tracked snake was noted as being opaque when it was observed and a freshly found shed was found outside the tin pile on 08/13/2011.

After leaving the tin pile the snake moved into pine/oak forest northeast of the “Stafford Triangle.” On 08/26/2011, it was relocated at an old mammal burrow that it had used in previous field seasons, as well as, earlier in this season. It then spent the next two weeks at this location where it went into a shed cycle, and was often observed basking next to the burrow entrance. After coming out of shed this snake spent the remainder of September in the disturbed pine forest that composes the “Stafford Triangle” or the pine/oak forest nearby. On one occasion it was found next to a large coyote burrow that was being occupied by study snake 2007.14 at the same time. Both these snakes were found in this coyote burrow in 2010 as well. On 10/07/2011, it moved back into NH 8 where it has overwintered every year of this radio-tracking study.

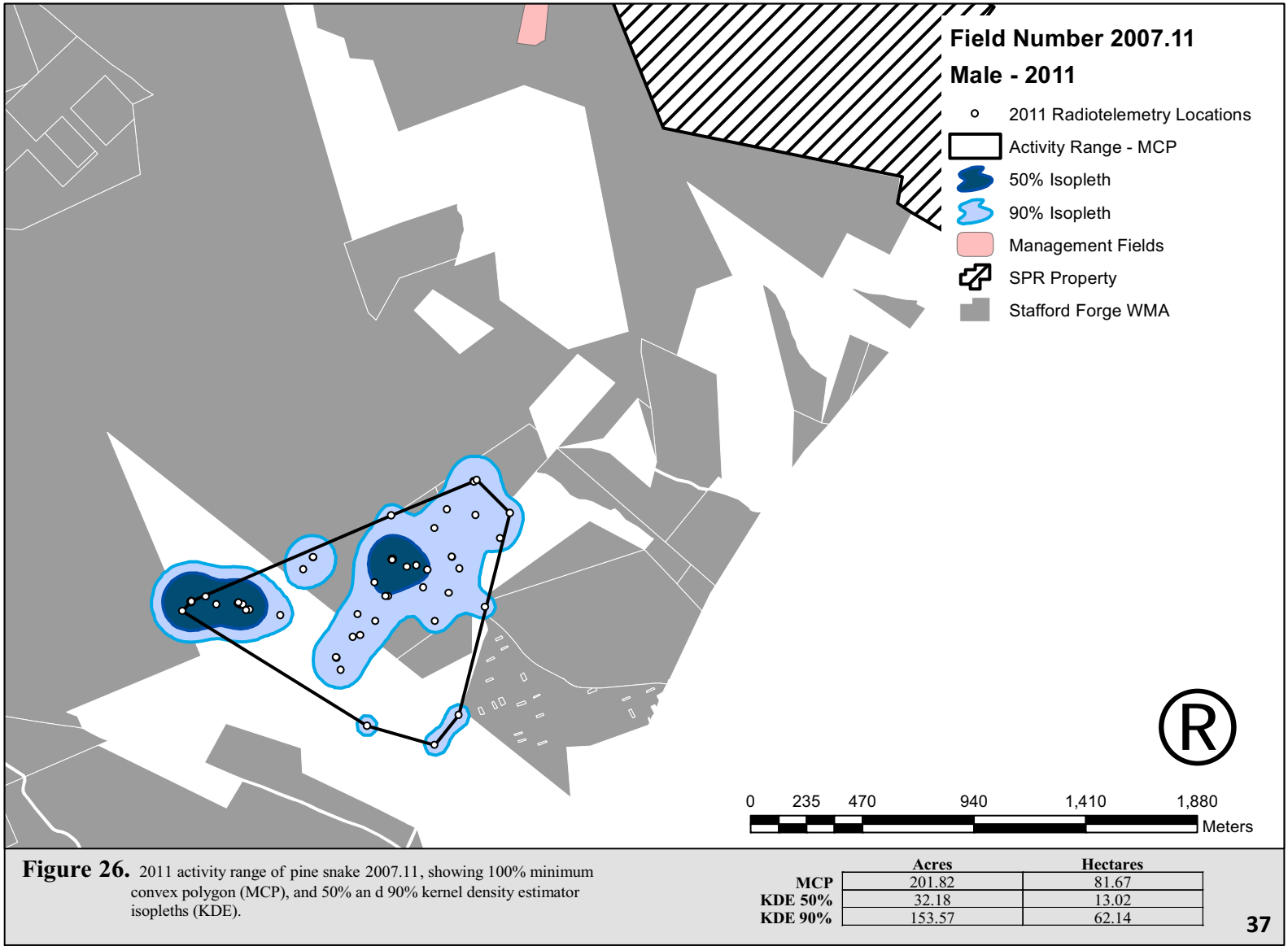




Figure 27. Pine snake number 2007.14, scent trailing nestling birds in their nest on a pitch pine tree. The dark patch of vegetation to the right of the picture, is a cedar waxwing nest. The adult birds were at the top of the tree scolding the snake. Photo by David Burkett, HA Staff.

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

This snake was found in a trap attached to the NH 8 corral on 04/20/2011 and released. It was relocated 98 times during the 2011 field season. Upon egress this snake remained near NH 8 for the first week before making a large move east into the pine/oak forest near the “Glass Pile.” On 05/03/2011, this snake was observed in courtship with an unknown female pine snake. HA staff remained at the location for approximately one hour waiting for the two snakes to finish mating so they could check the female for a PIT tag. Unfortunately, the snakes had not separated after an hour had passed and the biologist continued on with radio-tracking other snakes. Therefore, no PIT tag number for the female was obtained.

Throughout the month of May this snake was consistently relocated in the pine/oak forest near the “Glass Pile” and the “Turtle Pond” (refer to **Appendix IV** for frequently referenced landmarks), habitat that has been identified as a part of its home range in prior field seasons. On two occasions in May, this snake was found in areas with ample signs of small mammal activity. Once was near a stump hole and the other time was near a fallen pine tree. On both occasions there was a large amount of shucked pine cones in the area, suggesting red squirrels had been feeding at those locations. At the beginning of June this snake went to one of its known shedding stations in the Cedar Run wetland corridor. It has been opaque (a pre-shed condition), at this location every year of the study. It remained there for approximately a week and a half before shedding its skin.



Figure 28. The pine snake is constricting a nestling cedar waxwing in the nest. Photo by David Burkett, HA Staff.

On 07/04/2011, this snake was relocated approximately 10 meters (30 feet) up a pitch pine tree crawling along a branch. The observer continued to monitor the snake as it ascended into the top canopy of the pitch pine and proceeded to maneuver across the canopy of this particular pine tree into another adjacent pitch pine. The snake then began to descend the pitch pine that it had just crossed over to and crawled out onto one of the upper limbs of this tree. At the end of the limb the observer could see a nest fairly well concealed amongst the pine needles. The observer continued to watch as the snake slowly approached the nest (**Figure 27**). When it reached the nest the snake quickly struck its head into it grabbing a young bird (**Figure 28**). At this moment, two cedar waxwings flew in from the northwest and at first perched in the pitch pine not far from the snake's location while emitting distress calls. The waxwings then proceeded to perch in a dead oak tree adjacent to the tree that the snake was in while continuing to act in distress. Through binoculars the observer could see the pine snake systematically pulling young birds from the nest and consuming them one at a time (**Figure 29**). The whole observation lasted approximately 30 minutes.

Immediately following this feeding observation this snake went into a shed cycle underneath a fallen log in the pine/oak forest north of the "Glass Pile." It remained here for the next two weeks. After coming out of shed this snake was relocated foraging in the Cedar Run wetland corridor and in pine/oak forest established as part of its home range in prior radio-tracking seasons.

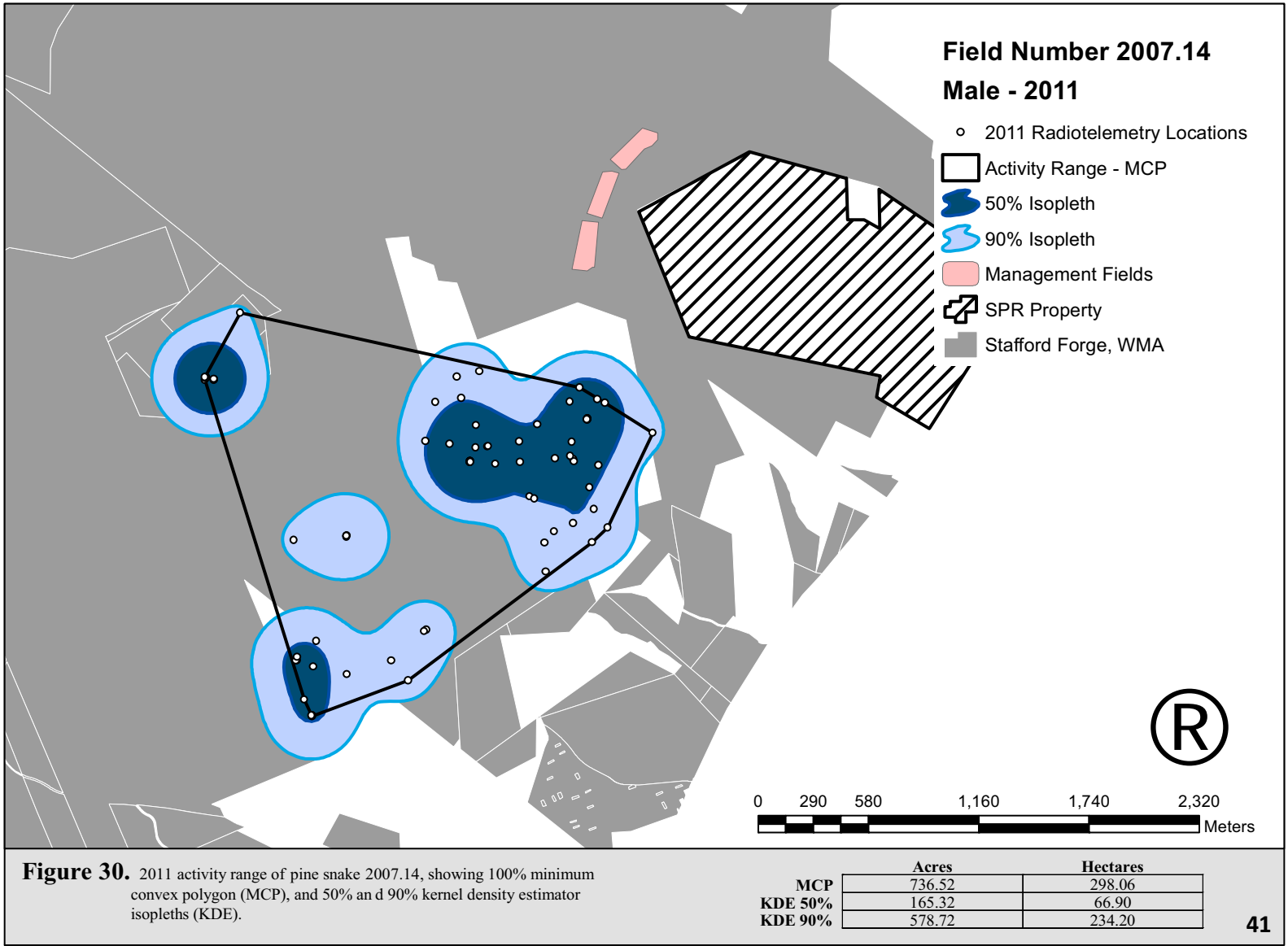
On 08/06/2011, it returned to the shedding station in the Cedar Run wetland corridor it was in earlier in the season and remained there for the entire month of August. The snake spent the majority of September in tracts of forest that had been previously identified as part of its home range during prior field seasons.



Figure 29. The pine snake is now swallowing the dead bird. It ate all the cedar waxwing chicks in the nest over a half hour period. Photo by David Burkett, HA Staff.

In late September this snake returned to the area known as the “Stafford Triangle” (refer to **Appendix IV** for frequently referenced landmarks). It was relocated in a large coyote burrow on 09/28/2011. At the same time study snake 2007.11 was relocated concealed amongst the shrub layer just outside of the burrow. Both these snakes had been recorded in this mammal burrow together back in 2010, at around the same time of the year. It remained within the “Stafford Triangle” for approximately a week and a half, and then moved into the large expanse of thick pitch pine forest, located between Micaja Road and the “Stafford Triangle.”

During the month of October, this snake continually moved between large mammal burrows within this section of the forest. It had been observed using these mammal burrows in prior field seasons. One of the burrows it was in was NH 27 a den where it had overwintered before and in which study snake 2006.108 is currently hibernating. However, this snake moved out of this den in early November and is currently overwintering in a moderate sized mammal burrow not far from NH 44.



N. Pine Snake No. 2008.02 (♂). Current status = Deceased. This snake was originally captured by HA staff while emerging from NH 3 on 04/16/08.

In the late fall on 2011 this snake was relocated at NH 25, a den previously used by pine snake number 2007.09. Over the following few relocations this snake was continuously found basking even though the air temperature was cool (~16.5 degrees C.), which is not thought to be suitable basking conditions unless a snake is in poor health. Also, during this period the snake's overall appearance continued to deteriorate (loss of weight was conspicuous). On 10/20/10, the snake was captured and evaluated. It had lost most of its body fat and was very thin (**Figure 31**). Obviously it had trouble finding prey and had not eaten much in 2010. It also appeared to have a respiratory problem.

Therefore, it was decided that the snake was not healthy enough to enter hibernation and survive the entire winter. HA staff tried to rehabilitate this snake in the laboratory during the 2010/11 winter. The snake occasionally fed, however it's health continued to decline and it died in the laboratory during the winter. A necropsy was performed, and it was noted that the snake's lungs were filled with mucous caused by a respiratory infection, which is what likely killed the snake. In 2011, there was no home range map generated for snake number 2008.02.



Figure 31. Male pine snake 2008.02, found basking near its den in the fall of 2010. Notice how thin the snake was from not regularly eating in the summer of 2010. Photo by Bob Zappalorti, HA.

N. Pine Snake No. 2008.03 (♀). Current status = Alive and healthy. This snake was originally captured by HA staff attempting to egress from a corralled natural den (NH 5), on 04/16/08.

On 04/19/2011, this study snake egressed from NH 5. It was relocated 86 times during the 2011 field season. Following egress each year, this snake makes a series of large moves north towards the Mill Creek wetland corridor. True to form, on its first post-egress relocation, this snake was found 400 meters north of its den at a location it has been observed at during previous field seasons. On 04/29/2011 it was relocated in the Mill Creek wetland corridor.

On 05/11/2011, this snake was observed in courtship with a large unidentified male snake. To prevent disturbing the two snakes, no attempt was made to identify the male. Another male, quite possibly the same one, was again noted in close proximity to this female on 05/13/2011. On 05/16/2011, this snake was again found in courtship, but this time it was with study male 2009.13 (**Figures 32** and **33**). The snakes were observed for approximately 90 minutes, yet no actual copulation was recorded. However, this snake did become gravid in 2011.

Following the courtship observations, this snake was recorded along a small sandy ridge in a section of severely burned upland pine forest, where it remained for approximately one month.

On 06/9/2011, this snake was found underground in what appeared to be a previously used pine snake nest. The structure sits in a 10m by 13m clearing of golden heather and bare sand. On 06/11/11 the snake had not moved from this location, and the sand fan outside the nest's entrance had grown noticeably. This nesting occurrence is of particular interest, as it represents a new nesting location not only for this snake, but for the study as well. No snakes had ever been recorded nesting



Figure 32. Radio-tracked male pine snake 2009.13, is mating with female 2008.03, on May 16, 2011. Photo by David Burkett.

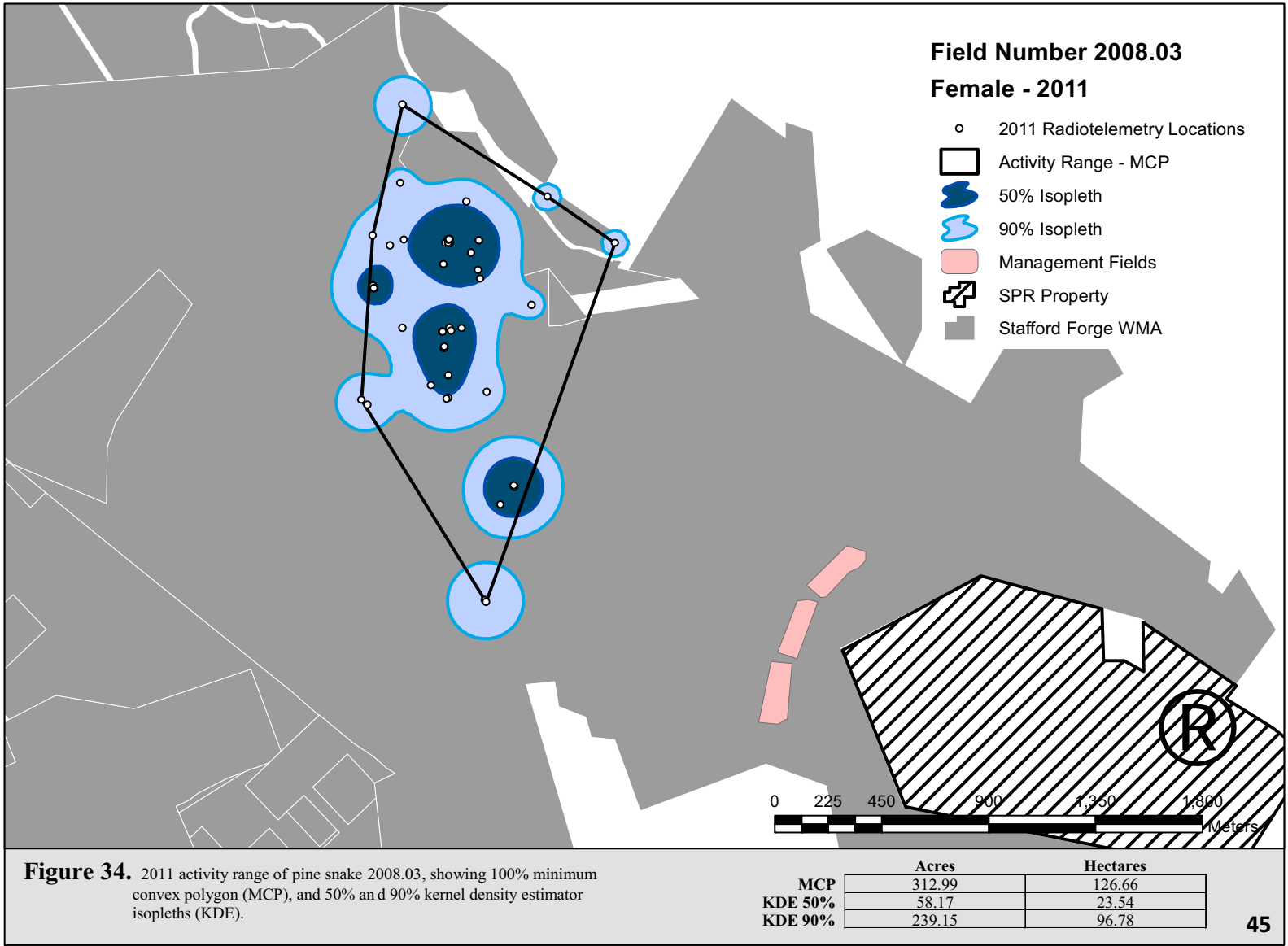
at this location in the past. In fact, when this snake was gravid in 2009 it had nested in the area known as the “Stafford Triangle” (refer to **Appendix IV** for frequently referenced landmarks). After nesting, this snake made a large move out of the area, traveling west and eventually returning to habitat near the Mill Creek wetland corridor where it had been found earlier in the season.

This snake then spent the remainder of the activity season in two particular sections of Stafford Forge WMA. It was either found near Mill Creek along the north side of Hay Road, where it was often located within stump holes, fallen logs, red-squirrel feeding stations, or in the selectively cut forest along the south side of Hay Road. When it was in the selectively cut forest, it was often found in the woody debris and brush piles left behind by the forest fire service.

At the end of the season, the snake began moving south through the severely burned pine forest. It was thought, at the time, that this snake was moving back towards the den (NH 5) it has shown fidelity to during the entire course of the study. However, it selected a new previously unidentified den site approximately 500 meters north of NH 5. This new den has been designated as NH 45.



Figure 33. Male pine snake 2009.13, mating with radio-tracked female 2008.03. Photo by David Burkett, HA Staff.



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

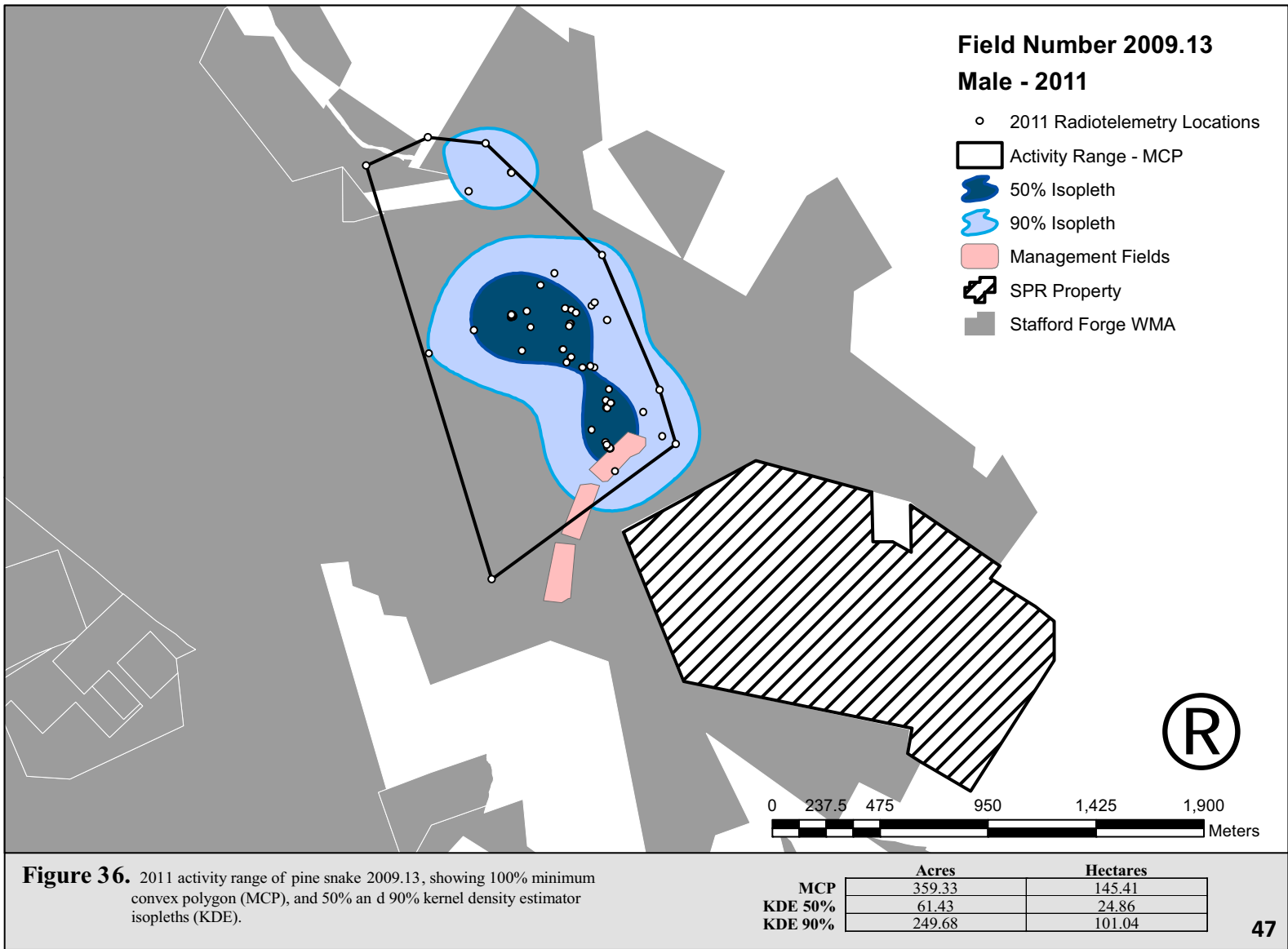
This snake egressed from NH 40 on 04/21/2011. It was relocated 101 times during the 2011 field season. For the first few weeks, this snake was relocated not far from its den location in the selectively thinned forest along the south side of Hay Road. It was often found in brush piles, large woody debris, and uprooted bases of pitch pines. On 5/16/2011, this snake was recorded in courtship with study female 2008.03 (see **Figure 32** and **33**). No additional mating observations were made of this snake during 2011.

On 07/8/2011, this snake was pulled for transmitter replacement surgery. Immediately following release, this animal moved into the berm along the west side of MF 3, where it remained for several relocations. This particular location had been frequented by this snake earlier in the field season, as well as in prior years. In each instance, this snake spent multiple relocations unseen within the berm before emerging with a freshly shed appearance.

After coming out of shed, this snake returned to the selectively thinned forest along Hay Road. It then moved into habitat north of Mill Creek. It was also relocated within the Mill Creek wetland corridor during this time. These areas of Stafford Forge WMA were identified as part of this snake's home range in 2010. At the beginning of October this snake began to move back towards its den (**Figure 35**) and by 10/12/2011 this snake had returned to NH 40.



Figure 35. Pine snake 2009.13 traveling towards its winter hibernaculum in the fall of 2011. Photo by Bob Zappalorti, HA.

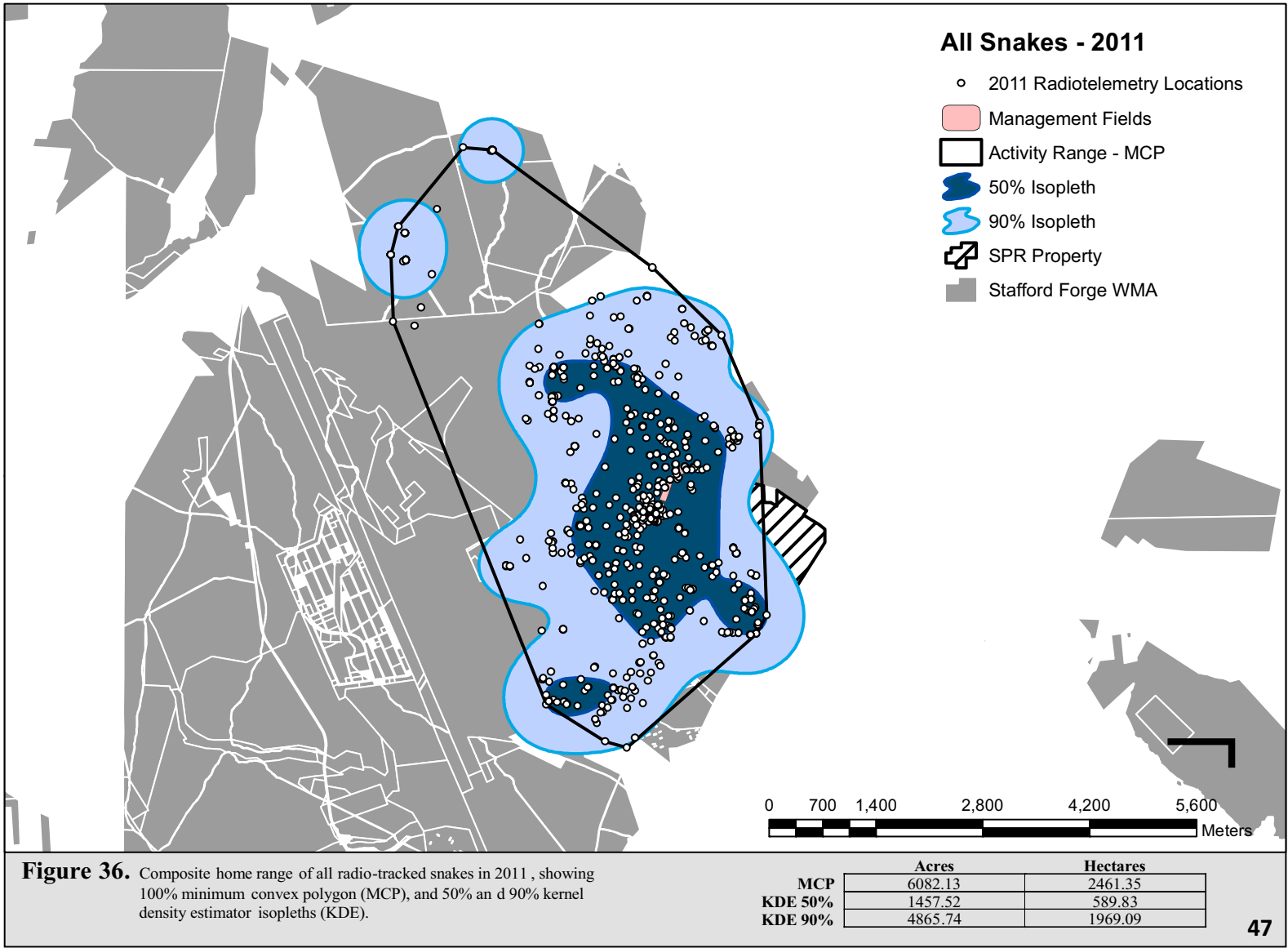


HOME RANGE ANALYSIS

Table 3 shows the Minimum Convex Polygon (MCP) home range area in acres and hectares for each individual snake radio-tracked during the 2010 field season, as well as, the 50% and 90% isopleth kernel activity home range analysis, using both Minimum Convex Polygon and Kernel home range methods of analysis (Samuel et al, 1985; Tiebout and Carey 1987; Seaman and Powell 1996).

Table 3. MCP in Acres and Hectares and Kernel Activity Range (Both 50% and 90 % Isopleth) Home Range Sizes for 13 Radio-tracked Pine Snakes in 2011.								
HA Snake Field ID Number	Sex	Number of Relocations	Minimum Convex Polygon		50% Kernel Home Range Isopleth		90% Kernel Home Range Isopleth	
			Acres	Hectares	Acres	Hectares	Acres	Hectares
2006.08	F	73	229.70	92.95	44.83	18.14	179.09	72.47
2006.16	M	104	333.83	135.09	30.51	12.34	234.84	95.03
2006.19	F	104	95.38	38.60	14.19	5.74	71.58	28.96
2006.34	M	96	255.76	103.50	48.80	19.75	198.43	80.30
2006.49	M	56	136.13	55.09	23.04	9.32	105.79	42.81
2006.108	M	77	545.44	220.73	113.50	45.93	418.37	169.31
2007.07	F	71	381.12	154.23	85.42	34.56	310.89	125.81
2007.09	M	69	1087.96	440.28	188.81	76.60	793.72	321.21
2007.10	M	84	214.89	86.96	40.72	16.48	167.39	67.64
2007.11	M	93	201.82	81.67	32.18	13.02	153.57	62.14
2007.14	M	98	736.52	298.06	165.32	66.90	578.72	234.20
2008.03	F	94	312.99	126.66	58.17	23.54	239.15	96.78
2009.13	M	101	359.33	145.41	61.43	24.86	249.68	101.04
N=13	9m:4f							

Figure 37 shows all of the 2011 radio-tracked pine snake relocations and an MCP and Kernel analysis of all the points. This map depicts the overall MCP and Kernel home range for all of the radio-tracked pine snakes combined.



HABITAT USE AND BEHAVIORAL ANALYSIS

Radio-tracking and monitoring of northern pine snakes at the SPR property and the adjacent Stafford Forge WMA, revealed some interesting habitat preferences by the study snakes. **Table 4** and **Figure 39** provide a comparison by percent of the habitat selected by the shifted versus non-shifted pine snakes during the 2011 field season (McCormick 1970 and 1979, Burger and Zappalorti 1989a, Boyd 1991). **Figure 40** shows a comparison by percent of the most frequent behaviors observed by free roaming pine snakes within Stafford Forge WMA in 2011.

For the purpose of this investigation, habitat types used by northern pine snakes in 2011 were defined as follows:

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

Artificial Hibernaculum - artificial snake shelter or den, designed and constructed by HA and located in the management fields.

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

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

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

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

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

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

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

Selectively Thinned Forest – area of forest within Stafford Forge Wildlife Management Area that was selectively thinned by the New Jersey Division of Parks and Forestry.

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

Table 4. Habitat Preferences of Radio-tracked Pine Snakes at Stafford Forge WMA and the Stafford Park Redevelopment Property in 2011.						
Habitat Types	All Snakes (n = 1132)		Shifted Snakes (n = 520)		Non-Shifted Snakes (n =612)	
	Number of Relocations	Percent of Total	Number of Relocations	Percent of Total	Number of Relocations	Percent of Total
Artificial Hibernaculum	45	3.98%	45	8.65%	0	0.00%
Selectively Thinned Forest	21	1.86%	2	0.38%	19	3.10%
Barren Ground/Disturbed	2	0.18%	2	0.38%	0	0.00%
Open Field	18	1.59%	18	3.46%	0	0.00%
Ecotone Between Field and Forest	48	4.24%	46	8.85%	2	0.33%
Ecotone Between Upland and Wetland	33	2.92%	10	1.92%	23	3.76%
Forested Wetland	57	5.04%	21	4.04%	36	5.88%
Ecotone Between Forest and Barren Ground	11	0.97%	1	0.19%	10	1.63%
Oak/Pine Forest	137	12.10%	56	10.77%	81	13.24%
Pine/Oak Forest	258	22.79%	80	15.38	178	29.08%
Pine Forest	502	44.35%	239	45.96%	263	42.97%
Total Relocations	1132	---	520	---	612	---



Figure 38. A hognose snake eating a Fowler's toad. Photo by David Burkett, HA Staff.

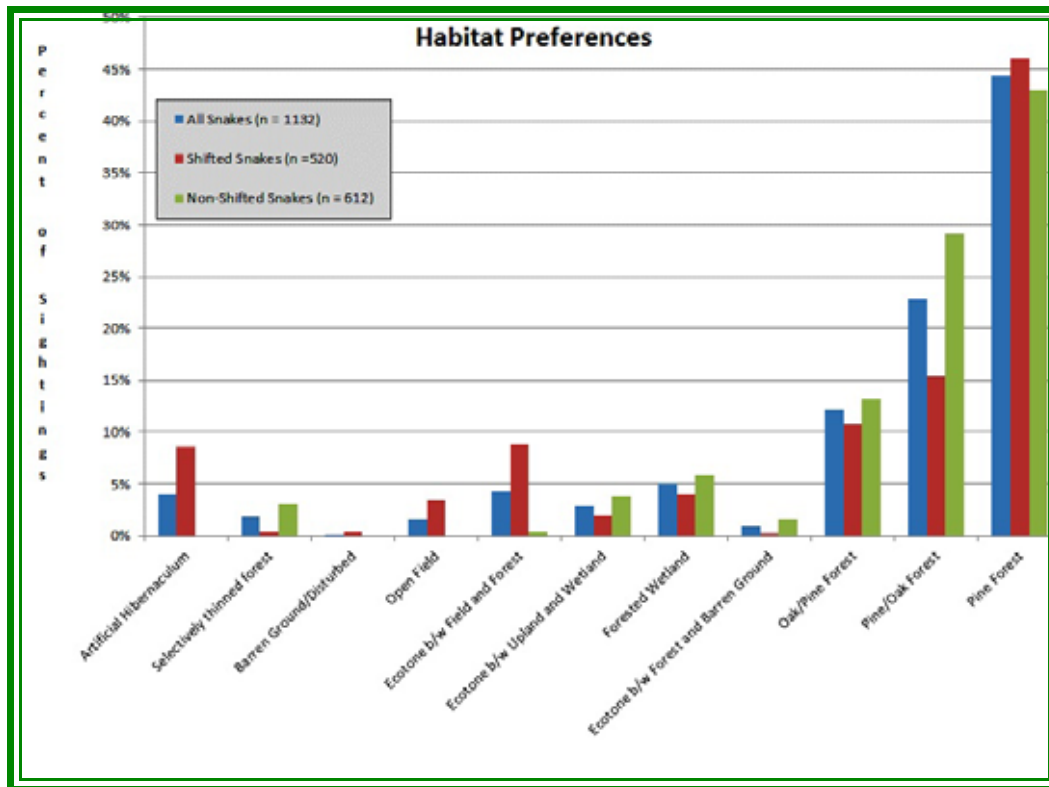


Figure 39. This bar graph illustrates habitat preferences and use by 14 radio-tracked northern pine snakes over the course of 1132 relocations. As shown by percent, clearly pitch pine forest, pine-oak forest and oak-pine forest are the most frequently used habitat types.

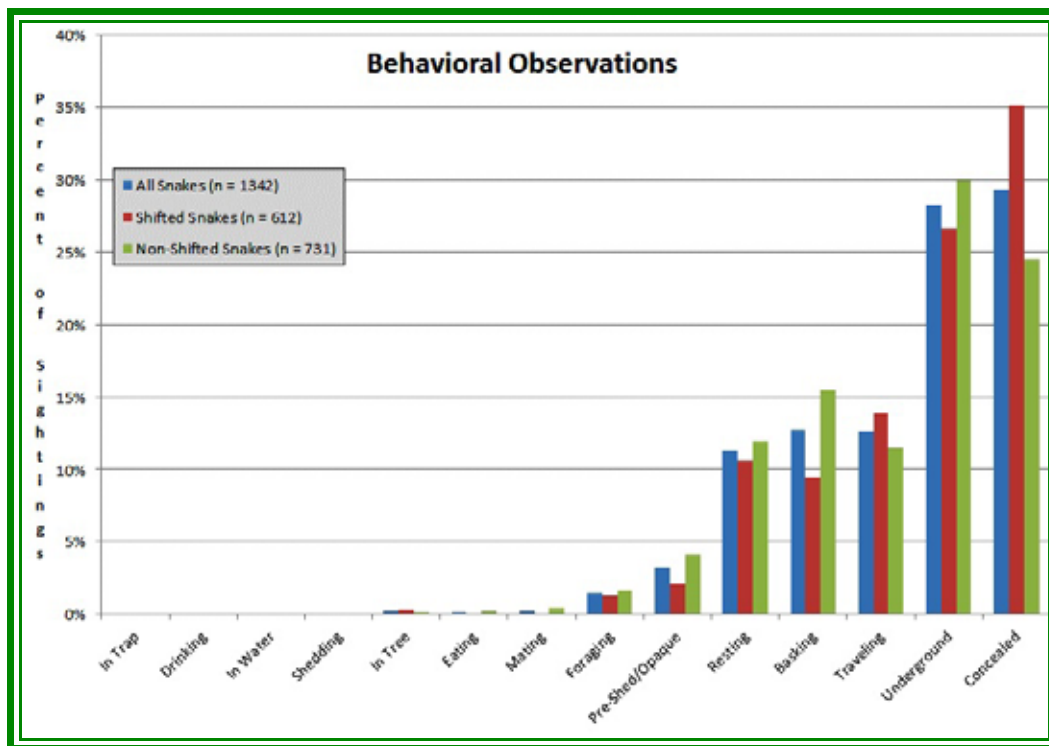


Figure 40. This bar graph shows the percentage of different behavioral observations of 14 radio-tracked northern pine snakes over the course of the 2011 activity season. Concealed in debris on the surface, hidden underground, basking and traveling were the most frequently observed snake activities seen by HA staff.

Use of Fire-Altered Habitats

The response of pine snakes to the May 16, 2007, forest fire-altered habitat was most obvious by their selection of microhabitat locations within the Stafford Forge WMA. During the period immediately following the fire, snakes sought cover in pine stump holes, mole tunnels, or at the base of pitch pines under the growth of the new basal branches. Over the last five years the forest has continued to regenerate.

Although the overstory canopy has remained sparse in areas where the fire had crowned and burned particularly hot in 2007, the understory shrub layer has become a dense mixture of new growth pitch pine, black-jack oak and scrub oak saplings, and various shrub and fern species. In particular, pitch pine and scrub oak have formed a dense understory layer in the upland pine forest, west of the management fields, giving that habitat a similar appearance to the pygmy pine forest of the east and west Pine Plains to the northwest of Stafford Forge WMA.

In addition, the Mill Creek and Cedar Run wetland habitats that bisect the study site have continued to rebound. Although, several areas where the fire burned hottest still have little in the way of overhead canopy, highbush blueberry, inkberry, dangleberry and red maple saplings have returned to form a dense understory within the wetland corridors (**Figure 41**). Several of the study snakes have been recorded using this vegetation to seek shelter from the summer heat and possibly potential predators.



Figure 41. This photograph was taken in early May 2011, showing a northern view of the Cedar Run wetland corridor five-years after the major forest-fire in May 2007. Notice the thick underbrush consisting of inkberry, huckleberry, sweet red maple and highbush blueberry. Photo by David Burkett, HA Staff.

THREE EXPERIMENTAL SNAKE TREATMENTS

At the end of the 2011 field season, only five snakes remained alive from the three treatment study groups. Below are brief histories of each treatment set and which snakes still remain from each study group.

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

There were 12 snakes (not including hatchlings) in “Treatment A”, 9 of which were originally implanted with radio transmitters. The other three snakes were sub-adults and were too small to surgically implant. Instead, they were PIT tagged (Elbin and Burger 1994), placed into the one winter treatments in the fall of 2006, and subsequently released into the wild in 2007. A radio-tracked snake from this treatment had died during each previous year of the study (2006, 2007, 2008, 2009 and 2010), from either raptor predation, the forest fire, mammalian predation, or other unknown causes (refer to **Appendix II** for the Deceased Snake Synopses). At the beginning of the 2011 field season there was only one original radio-tracked snake (Pine Snake 2006.34) from this treatment that was still alive. It survived the 2011 field season and is currently overwintering in a newly identified natural den.

In early 2010, a non-radio tracked male pine snake was found mating with female study snake 2006.19. This male snake was pine snake 2006.108, one of the three “Treatment A” sub-adult snakes too small to implant in 2006. After it finished mating, HA staff collected it for reprocessing. It was determined that it had grown to a sufficient body weight to be implanted with a transmitter. Since the original “Treatment A” data set of snakes had suffered such a high mortality rate during the course of the study, HA staff with consultation from Dave Golden, decided that this snake should be implanted with a transmitter and introduced into the radio-tracking portion of the study. This snake is still alive and healthy and is in a previously identified natural den. Therefore, at the conclusion of the 2011 field season, there are two pine snakes left from “Treatment A” being actively radio-tracked (excluding hatchlings).

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

There were originally 9 snakes (not including hatchlings) within “Treatment B”, 8 of which were radio-tracked adults. The other was a juvenile snake too small to radio-track at the time. Seven snakes from this treatment (Field Numbers 2006.06, 2006.10, 2006.13, 2006.20, 2006.22, 2006.23 and 2006.27), have died during the course of the five year study (refer to **Appendix II** for the Deceased Snake Synopses). This left only one radio-tracked snake, (female pine snake 2006.29), alive at the beginning of the 2011 field season. Unfortunately, this snake never emerged in the spring from its den and is considered deceased by HA staff (refer to Snake Synopses and Home Range Maps). As a result of this snake’s death, there are no longer any “Treatment B” snakes left in the study.

Treatment C Snakes (One Winter in HA Lab):

Eight adult snakes with radio-transmitters originally comprised the “Treatment C” study set. These snakes overwintered in HA’s laboratory during the 2006 - 2007 winter, due to various health reasons, and were released into AH 1, AH 4 and AH 6 (all two winter treatments) in the spring of 2007. At the beginning of the 2011 field season only three snakes (2006.08, 2006.16 and 2006.19) from “Treatment C” remained. All three snakes were radio-tracked through the majority of the 2011

activity season. Unfortunately, in late fall as the snakes were returning to den sites, pine snake 2006.08 went missing (refer to Snake Synopses and Home Range Maps). HA will continue to search for this snake throughout the winter and spring. The two other remaining snakes from this treatment have returned to artificial dens in the management fields and are overwintering in them.

NON-SHIFTED PINE SNAKES

In order to provide a direct comparison with shifted snakes, a control group of non-shifted resident pine snakes (**Figure 42**) have been fitted with radio-transmitters. The behavior and movement patterns of these non-shifted snakes are monitored and recorded simultaneously and via the same methodology as the shifted pine snakes. A total of 7 non-shifted snakes were radio-tracked in 2011, of which five were captured in 2007, one in 2008, and one in 2009. All of these snakes were captured using various survey techniques, including drift fence trapping, random opportunistic searching, time constrained searching, road cruising and natural den corralling.

All non-shifted snakes have overwintered in natural dens located within their home ranges identified through radio-tracking efforts during the past five field seasons. In 2011, four of these snakes (Field Numbers 2007.07, 2007.09, 2007.11 and 2009.13) returned to the same overwintering sites they used the previous year and three snakes (Field Numbers 2007.10, 2007.14 and 2008.03) selected new den locations. None of the non-shifted snakes have yet to be recorded using the artificial dens.

HISTORY OF HATCHLING PINE SNAKES (2006 - 2011)

In 2006, HA released 71 hatchling pine snakes, from clutches found on the landfill (**Figure 43**), into the artificial dens. Since then, HA staff has attempted to continue accounting for these hatchlings by trapping the artificial dens during the spring egress, as well as, a select few of the natural dens that have been identified through radio-tracking efforts.



Figure 42. One of the non-shifted radio-tracked pine snakes coiled up on the forest floor. Photo By Bob Hamilton, HA staff.



Figure 43. Eggs from one of the nests found on the landfill in the summer of 2006. The eggs were incubated in HA's lab. Once the neonates hatched out, they were PIT tagged and released into the artificial dens. Photo By Robert Zappalorti, HA staff.

From 2007 to the present, HA has captured many new neonates within the confines of the management fields, in the Stafford Triangle and at other locations in the surrounding habitat. HA continues to monitor the survivorship, growth and development of these hatchlings through mark and recapture studies (all hatchlings are fitted with micro-chip PIT tags).

2006 Hatchlings

Only one of the 2006 hatchling pine snakes was recaptured during 2011. This was pine snake 2006.49. It was found in a trap attached to AH 1 in late April. It had been recaptured on two occasions in the past, once in 2008 in a perimeter drift fence trap and once in 2009 in a trap attached to AH 1. On both occasions, the snake was considered to small to implant with a transmitter. However, when recaptured this year it was determined to have sufficient body weight to be implanted. It is currently a part of the radio-tracking study (refer to Snake Synopses and Home Range Maps).

2007 Hatchlings

In 2007, HA captured 10 hatchling pine snakes in AH 4 and AH 6. Of these 10, only one was recaptured in 2011 (it is also the first one to be recaptured since the hatchlings were initially processed and released back in 2007). This was pine snake 2007.23, which was originally captured near AH 4 on 09/25/07. It was found in a trap attached to the corral around NH 2 (a natural den located in the forest approximately 70 meters west of MF 3) on 04/20/2011. It has matured into a good sized adult snake. None of the other 2007 hatchlings have ever been recaptured by HA staff and it is unknown what has happened to them.

2008 Hatchlings

In 2008, HA captured and PIT tagged 11 new hatchling pine snakes. Nine of the snakes were from a nesting/denning location (NH 8) south of the SPR property in Stafford Forge WMA. No hatchling snakes with a 2008 field number were recaptured in 2011.

2009 Hatchlings

In 2009, HA staff captured and PIT tagged 37 new hatchlings and three young of the year (snakes that hatched out in 2008). The three “young of the year snakes” were caught in the artificial den traps during the spring egress. One of these, 2009.12, was again found in an artificial den trap in the spring of 2011.

In the late summer of 2009 HA also found a hatchling pine snake concealed under a cover board approximately 1 meter up a large earthen mound at the far north end of MF 3. Two radio-tracked females (field numbers 2006.29 and 2007.15) had nested at the top of the mound. It is therefore, highly likely this hatchling was from one of those nests. Also, a dead hatchling was found under a small log above the entrance of one of the aforementioned nests.

The vast majority of 2009 hatchling pine snakes came from the “Stafford Triangle” (refer to **Appendix IV** for frequently referenced landmarks). Two natural dens, multiple pine snake nests and hatchling pine snakes have been observed within this area of forest throughout the course of the study. A nest was located in this disturbed habitat, via radio-tracked female pine snake 2008.03 in 2009. Upon relocating this snake in her nest, another nest was observed in close proximity. Both nests were corralled by HA staff in order to PIT tag any hatchlings emerging in the fall. A total of 25 pine snake hatchlings were found in the two enclosures. HA staff also captured 6 pine snake hatchlings basking near the entrance to NH 8 in the late summer and early fall of 2009. None of these PIT tagged 2009 hatchlings were recaptured in 2011.

2010 Hatchlings

In 2010, HA staff radio-tracked three female pine snakes that were gravid. Two of these females nested in the berm along the western edge of MF 1 and the other nested along the western edge of the SPR property, about 4 meters from the edge of the forest. In an attempt to capture some of the pine snake hatchlings in late summer, before the eggs began to hatch, HA placed cover boards around the known nest chambers in MF 1. However, no hatchlings were captured or seen under the cover boards or near the nest chamber in the fall of 2010.

The nest on the SPR property was corralled by HA staff and Dr. Walt Bien’s graduate students from Drexel University, to conduct an experimental study on scent trailing and directional orientation of hatchling pine snakes. Additionally, HA staff was curious to see if this nest would produce any hatchlings, considering it was thought to be a poor location for a nest. The nest produced 10 hatchlings in the fall (**Figure 44**). These snakes were processed by HA and Drexel students and then released outside the corral walls when the experiment was completed. None of these hatchlings were recaptured in 2011.

HA staff also found signs of new hatchlings at the only other known nesting area on the study site, the “Stafford Triangle”(refer to **Appendix IV** for frequently referenced landmarks). HA once again found evidence of pine snake hatchlings at NH 8, when several hatchling sheds were found outside of the den entrance in late summer. HA staff also found hatchling sheds under cover boards at a previously known nest site further south in the “Stafford Triangle.” However, even though the area was searched on multiple occasions, HA staff never observed any hatchlings at either of these locations.



Figure 44. Hatchling pine snake found under a cover board next to the nest on the SPR property in 2010. Photo by HA staff.

However, HA staff did capture several young pine snakes in the artificial and natural den traps in the spring of 2011. One was found in a trap attached to AH 1. All others were found in the traps attached to the corral surrounding NH 8. Even though these snakes were determined to be from clutches laid in 2010 based on their size, they were assigned 2011 field numbers since they were captured during the 2011 field season.

2011 Hatchlings

HA staff caught 30 hatchling pine snakes in 2011. Six of the hatchlings were found in the management fields and traps attached to the artificial dens in late summer and early fall. Another twenty four came from two nest sites in the “Stafford Triangle” (see Breeding and Nesting Observations). Five of the six hatchlings found in the management fields are currently overwintering in the artificial hibernacula. **Figure 45** shows a hatchling captured in the traps. Although, HA staff



Figure 45. A neonate found in a trap attached to AH 6 this past fall. It was PIT tagged and released into the den. Photo by Bob Hamilton, HA staff.

were checking the den traps every day, one hatchling was unfortunately found deceased in a trap (this hatchling had originally been captured under a cover board in the fields on 09/15/2011). It is unknown what caused this snake to die in the trap. When it was discovered it had been partially consumed and there were several large beetles in the trap with the snake. Whether the beetles played a part in the snake’s death is impossible to determine.

USE OF MANIPULATED AND ENHANCED HABITAT

In 2011, HA once again recorded extensive use of the management fields by the study snakes. Not only have the artificial dens been used by study snakes to overwinter in every year of the study, but the earth berms that surround the management fields are also widely used by the pine snakes throughout the field season for a variety of reasons. In 2011, a total of six study snakes were recorded using the berms for shedding, foraging and concealment. All six have been located in the management fields in prior field seasons indicating that the snakes have imprinted on the fields as suitable habitat for different behavioral needs.

In prior years, the management fields and berms have been used by study snakes and non-study snakes for nesting purposes. In 2011, no study snakes were recorded nesting in the management fields. However, HA is fairly certain that at least one non-study snake nested in the management fields. Two observations allude to this conclusion. First, a hatchling was found on 09/15/2011 concealed under a piece of plywood along the berm of MF 2. This plywood was placed there in 2008 when a radio-tracked snake was recorded nesting in the berm at that location. Second, as previously mentioned, HA staff captured another five hatchlings in the artificial den traps that were attached during the fall ingress. Finding hatchlings in the management fields in the late summer and early fall strongly suggests there was a nest somewhere in the vicinity of the fields.

Below are brief descriptions of the behavior exhibited by study snakes when located in the management fields and adjoining habitat in 2011:

Pine Snake 2006.08:

Throughout the study, this snake has consistently utilized NH 2, a natural den just behind AH 6 contained within the original MF 3 corral area. While not as extensively as in prior seasons, this snake repeatedly frequented the interior of MF 3's berms during shed cycles throughout 2011. In addition to the earth it was also located in the earth mounds along the MF 3 outer corral path. As previously mentioned, this snake went missing towards the conclusion of the 2011 field season, and it is currently unknown if the snake has returned to NH 2 (with an expired transmitter), or possibly deceased. HA hopes to resolve this question in 2012.

Pine Snake 2006.16:

This snake has overwintered in AH 1 every year of the study. This snake often forages in oak/pine and pine/oak forest south of the MF's. However, it consistently returns to a large sand pile in the southwest corner of MF 1 at various times throughout the field season. It has been recorded in this same location every field season. Whenever it returns to this location it is not seen above ground for an extended period of time (often up to two weeks), then emerges freshly shed. It is highly probable that this snake is using the berm as a shedding station.

Pine Snake 2006.19:

Each season this snake is relocated in and around the management fields on a regular basis. It has been found using the fields for all behavioral purposes, including foraging, nesting and denning. This was again the case in 2011 except for nesting, since it never became gravid. It was often found in the earth mounds created during the construction of the outer corral path of AH 1. Although this snake has hibernated in AH 1 every year of the study, it is currently overwintering in AH 2 this winter.



Figure 46 Snake shedding alongside one of the berms in the management fields. Several of the study snakes have been found in and near the berms of the management fields during their shed cycles. Photo by Robert Zappalorti, HA staff.

Pine Snake 2006.41:

This snake hibernated in AH 1 last winter. It was also recorded hibernating in AH 1 during the 2008/2009 winter. After being implanted with a transmitter this season it moved away from the management fields. It only returned to the fields on one occasion towards the end of the season when it was found concealed in one of the large earth mounds in the middle of MF 1. It did not return to AH1 to overwinter this year.

Pine Snake 2006.108:

This snake was relocated in the berms around MF 1 on three occasions during April and May, but only returned once to MF 1 in late summer.

Pine Snake 2009.13:

In prior years, this snake has been relocated multiple times in and near the management fields. In 2011, it was located multiple times within the vicinity of MF 3, the longest of such visits being between 06/05/2011 and 06/17/2011. Most of that time (06/07/2011 to 06/15/2011) was spent in a section of berm along the western edge of MF 3. Based on its behavior at this location (inside the berm and unmoved for several relocations), it is believed that it serves as a high-fidelity shedding station for this snake (**Figure 46**).

ENVIRONMENTAL INSPECTIONS AND SITE MONITORING

Most of the habitat alteration, disturbance and construction of the licensed landfill on the SPR property was conducted between 2007 and 2010. However, in 2011 a small portion of forest was cleared along the southern edge of the SPR property in preparation for the development of the new Stafford Preserve Luxury Apartment complex. HA staff was made aware of the clearing and was on site during the tree cutting and removal process. Since the drift fence surrounding the property was removed in the spring of 2011, there was no barrier hindering snakes or other small wildlife from entering the SPR property. As a result, HA staff conducted random sweeps of the construction areas and the new landfill on a regular basis to check for any pine snakes or other animals that may have accessed the property. No snakes were observed on the landfill during these sweeps. However, HA staff did observe a DOR garter snake on the road near the animal shelter in late August.

In prior field seasons a few of the radio-tracked pine snakes had ventured onto the SPR property, with one female nesting on its edge in 2010. In 2011, none of the radio-tracked snakes were ever observed on the SPR property. However, because of the prior nesting observation, HA conducted intensive surveys across the SPR property during the known nesting season (mid June-mid July). No pine snake nests were observed on the new landfill, or anywhere on the SPR property during the 2011 field season.

Southern Gray Treefrog and Other Amphibian Monitoring

As part of the mitigation and management of rare species, Walters constructed a southern gray treefrog breeding pond in a portion of Retention Basin D, which is located in the northwest corner of the licensed landfill (close to the Stafford Forge WMA). As with all the other retention basins on site, only rainwater enters the breeding pond in Retention Basin D. This basin was chosen because adult treefrogs were heard calling in the close vicinity of Retention Basin D in May of 2008. The breeding pond was constructed in the Fall of 2008, so it was available as a breeding site for the treefrogs in the Spring of 2009. This pond was part of the mitigation plan to replace the lost breeding habitat for southern gray treefrogs due to construction of the Stafford Business Park. It has been successful in prior seasons by attracting mating frogs and toads, including southern gray treefrogs

In May 2011, Bob Zappalorti and Bob Hamilton (HA staff), attended a meeting of the Northeast Wildlife Society, and heard a lecture given by Dr. Kirsten Monsen and Dr. Lisa Hazard. Both scientists are from the Department of Biology and Molecular Biology at Montclair State University. The lecture was about Ranavirus (Family: Iridoviridae; Genus: Ranavirus) which are one particular group of deadly pathogens linked to massive infection and die-offs of amphibian populations (Daszak et al. 1999; Gray et al, 2009; and Green et al, 2002). Unfortunately, scientists do not fully understand how this pathogen is distributed geographically among amphibian populations. What is known, is that when conditions become ideal, the virus infects the adult frogs and toads, their egg masses and/or the tadpoles. When the tadpoles contract the virus it results in slow death due to hemorrhaging of the internal organs and ulceration of the skin (Daszak et al. 1999). Ranaviral infections most often occur in amphibian populations that breed in closed, unconnected standing water habitat such as vernal pools or retention ponds (Harp and Petranka, 2006).



Figure 47. Southern gray treefrog tadpole. Photo by Matt McCort, HA staff.

During a routine check of the artificial breeding pond (Retention Basin D) in the late Spring of 2011, Bob Zappalorti observed a large number of dead and dying green frog (*Lithobates clamitans melanota*) tadpoles. There were dozens of dead tadpoles floating on the surface of the pond and some were submerged on the pond bottom. Since this was a southern gray treefrog breeding pond, it was alarming to see all the dead tadpoles. Additionally, Fowler's toad tadpoles were observed feeding on the dead green frog tadpoles. Ranavirus can be transferred from infected specimens to non-infected individuals via physical contact (Jancovich et al., 2001; Brunner et al., 2004). So, if the green

frog tadpoles had died as a result of the virus, it was highly likely that the toad tadpoles observed feeding on the carcasses would also contract the deadly virus.

After learning about Ranavirus outbreaks in New Jersey at the Northeast Wildlife Society lectures, HA staff became concerned that the virus may be responsible for the sudden die off of tadpoles at the Southern Gray Treefrog breeding basin. As a result, HA contacted Dr.'s Kirsten Monsen and Lisa Hazard on May 14, 2011, to ask their opinion and to see if they would be interested in taking tissue samples for analysis. They were very interested in sampling some Pine Barrens amphibians and agreed to collaborate with HA on the project. Walters was informed and they allowed the Montclair scientists access to collect the first round of samples from the following locations on May 17, 2011. Two sampling stations were on Walters property and three were on Stafford Forge WMA. Samples were taken at the following locations:

1. Breeding Pond at Retention Basin D
2. Breeding Pond in Management Field Two
3. Vernal Pond West of Management Field Two
4. Hay Road Breeding Pond
5. Retention/Irrigation Pond by Costco.



Figure 48. Metamorphosing southern gray treefrog. Photo by Matt McCort, HA staff.

A traditional PCR (polymerase chain reaction) test was used to test all the tissue samples for Ranavirus. (Bollinger et al., 1999; Brunner et al., 2004; Fox et. al, 2006; Harp and Petranksa, 2006). All the green frog tadpoles at the Basin D breeding pond, as well as, green frog tadpoles from the breeding pond in MF 2 tested positive for Ranavirus. None of the Fowler's toad tadpoles tested positive during the first round of tests.

On a second visit to the Basin D breeding pond two weeks later, the Fowler's toad tadpoles were dead and dying. During a second round of tests these Fowler's toad tadpoles tested positive for Ranavirus as well. They most likely became infected while feeding on the dead green frog tadpoles. HA recommends that additional amphibian testing be done at these locations, and other locations in the Pine Barrens in order to better understand the adverse environmental ramifications Ranavirus may have on amphibian populations in southern New Jersey. It remains to be seen what adverse impact this pathogen will have on the southern gray and Pine Barrens treefrog populations at the SPR property and the surrounding Stafford Forge WMA habitat.

FORAGING AND FEEDING OBSERVATIONS

Over the past five years, HA has made several interesting feeding observations of the radio-tracked pine snakes (refer to our past reports from 2007, 2008, 2009 and 2010 for details). Given its vast size (approximately 7546.8-acres) and habitat type diversity, Stafford Forage WMA is rich with birds and small mammal resources. These ideal conditions provide an ample food supply for northern pine snakes and other top predators that live in the forest (Reynolds and Scott 1982; Burt and Grossenheider 1980; Fitch 1982 and 1999; Arnold 1993 and Boyd 2000).

Due to their secretive nature, pine snakes are rarely observed feeding in the wild. However, as a result of radio-tracking efforts, HA has had the opportunity to observe several of the study snakes feeding on different species of small mammals and birds. Pine snake prey availability and feeding is an important part of population survivorship (Arnold 1993). In 2011, HA staff witnessed the study snakes feeding on various prey items. **Table 5** below, details the three feeding observations made by HA staff in 2011.

Table 5. Foraging and Feeding Observations of Pine Snakes in 2010*		
Snake ID	Date of Observation	Species Consumed
2007.07	05/09/11	Young Cottontail Rabbits
2007.14	07/04/11	Cedar Waxwing Fledglings
2006.49	09/14/11	White Footed Mouse
*Refer to the individual snake synopses section for more detailed descriptions of feeding observations.		



Figure 49. Juvenile eastern cottontail rabbit. This young rabbit was seen fleeing from a nest being raided by a radio-tracked pine snake. Photo by Bob Hamilton, HA staff.



Figure 50 White-footed mouse. This is one of the most common prey items for pine snakes. Photo by Robert Zappalorti, HA staff.

ARTIFICIAL DEN MONITORING AND SNAKE USE

Pine snakes often share their winter dens communally (Carpenter 1953 and 1982, Gregory 1984, Burger et al, 1988, Burger and Zappalorti 2011). Among the six research questions in this study, is whether or not pine snakes will continue to den in the artificial hibernacula provided in the management fields as the years progress. This is easy to determine with the snakes that have radio-transmitters in them, however, HA is also interested in determining if any non-radio-tracked pine snakes are using the human-made dens. In order to determine how many snakes were overwintering in the artificial hibernacula (during the 2010/2011 winter) a trapping program was initiated in the early spring (March 2011). **Figures 51 and 52** show what the artificial den trap arrays looked like. HA not only trapped each entrance pipe to the dens, but also encircled the six artificial dens with silt fences and attached 3 traps to each one. In the past, HA had only connected the traps directly to the four entrance/exit pipes which was effective in catching several pine snakes, however, HA was concerned that some snakes may have been leaving the dens through entrances they may have excavated themselves. Therefore, by attaching traps to not only the entrance pipes, but also to the circular corrals around the outside of the dens, HA tried to ensure that any snakes that may have egressed from the dens without using the PVC entrance pipes, would be caught in the outer traps while trying to move away from the dens.



Figure 51. Trap array around artificial den three in management field two. Photo by Robert Zappalorti, HA staff.



Figure 52. Close up photo of the trap array around artificial den three. Notice that there are traps attached to both the PVC pipe entrance to the den inside the corral and to the drift fence surrounding the den. This way any snakes that may have egressed from the dens without using the pipes would be caught in the second set of traps. Photo by Robert Zappalorti, HA staff.

The traps were checked every day by HA staff until their removal on 06/01/2011. Through radio-tracking efforts and trapping, HA identified six pine snakes that had hibernated in the artificial dens during the 2010/11 winter. Five snakes were captured in traps attached to AH 1 and one in an AH 5 trap. Three of them had been previously recorded using AH 1 in prior winters (pine snakes 2006.16, 2006.19 and 2006.49). Another one (2009.12) was caught in an AH 1 trap in the spring of 2009 and 2010. In 2011, it was found in a trap attached to AH 5. One of the other two was a snake that was caught in 2010 (pine snake 2010.04) in one of the perimeter drift fence traps that surrounded the SPR property. The other was a young snake that, by its size, was determined to be a previously unaccounted for hatchling from a 2010 clutch. In addition to the six pine snakes, a young hognose snake was also recorded in an AH 1 trap.

HA also placed traps on the inside of the den corrals during the fall ingress to capture any snakes that were entering the dens for the 2011/12 winter. These traps were installed on 09/17/2011 and checked every day until their removal on 11/14/2011. As a result of the trapping and radio-tracking efforts in the fall, a total of nine pine snakes are known to be currently overwintering in the artificial dens. This includes two radio-tracked snakes and an additional seven previously unidentified pine snakes (5 hatchlings and 2 second year snakes). The seven unidentified pine snakes were measured, sexed and PIT tagged prior to being released back into the artificial dens.

This marks the fifth winter in a row (including the current 2011 - 2012 winter), that HA has had both hatchlings and adult pine snakes overwintering in the artificial dens. The neonates are most likely locating the artificial dens by scent trailing pheromones left by other pine snakes (Carpenter 1953, Ford 1978, and 1986, Gehlbach et al, 1971; Reinert and Zappalorti 1988b, Burger 1990 and 1991), that are either currently, or have in the past, overwintered in the artificial dens.

NATURAL DEN MONITORING AND SNAKE USE

HA staff, in conjunction with Dr. Walter Bien and his students from Drexel University, also corralled and trapped natural dens in Stafford Forge WMA. These natural dens were identified through HA's radio-tracking efforts. The Drexel students were taking blood samples from different pine snake populations in the Pine Barrens as part of a larger DNA study. Drexel was testing the DNA of the snakes for genetic similarities and/or differences between population localities. A total of three natural dens were corralled at the beginning of April 2011. These were natural dens 2, 8 and 39. These three dens were corralled, because HA felt they had the highest potential to produce multiple snakes. In fact, natural dens 2 and 8 had been corralled during previous field seasons with multiple snakes being captured at both locations. In 2011 natural den 8 produced the largest number of snakes, with 15 pine snakes being captured there, including the two radio-tracked snakes that were already known to be in the den. Natural den 39 held 8 snakes, including one radio-tracked

of snakes, with 15 pine snakes being captured there, including the two radio-tracked snakes that were already known to be in the den. Natural den 39 held 8 snakes, including one radio-tracked snake, and natural den 2 produced five snakes also including one radio-tracked snake.

During the mid-summer months of 2011, temperatures were hot with little rainfall. As a result, many pine snakes spent a large amount of time underground to escape these dry, warm conditions. This behavior is known as estivation, which means the snake remains dormant during hot, dry periods (Conant and Collins 1991, Greene 1997). Snakes will use mammal burrows, stump holes and root systems of dead trees to hide until weather conditions improve (Gillingham and Carpenter 1976, Burger et al 1988). Interestingly, none of the pine snakes returned to their winter dens during estivation periods, but instead found similar type refugia on the forest floor during the hotter summer months. HA observed many examples of snake estivation during 2011, especially in July, August and early September.

PINE SNAKE FIDELITY TO WINTER DENS

Over the course of the past five-years of radio-tracking pine snakes, HA has found and identified 45 different natural winter hibernacula or dens in Stafford Forge WMA. This is a land-area of approximately 7546.8-acres (or 3054.2-hectares). **Figure 53** shows a breakdown of these various hibernacula types by category, but in general they fall into three identifiable types of natural dens as listed below:

Natural Den Types

- 1). A naturally fallen (wind blow-down), or cut decayed tree stump and root system.
- 2). A large abandoned mammal burrow (e.g., coyote, fox, or woodchuck).
- 3). A small abandoned mammal burrow (e.g., skunk, red squirrel, or chipmunk) (**Figure 54**).

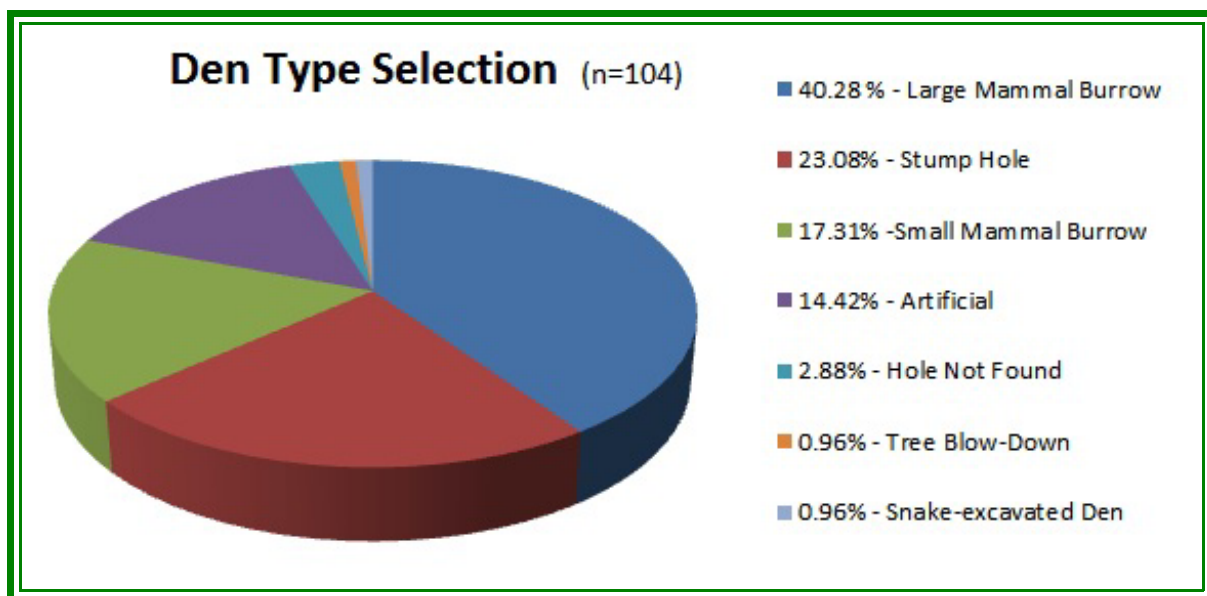


Figure 53. Chart depicting percentage of den type selected by the radio-tracked pine snakes during the last four winters when all the study snakes were free to choose overwintering locations.

As in previous HA studies, some of the pine snakes have shown a strong fidelity to a particular den while others have used multiple dens within their home ranges (Burger et al, 1988, Burger and Zappalorti 2011). **Table 6** shows how some pine snakes shifted from one natural den to another while other pine snakes demonstrated a fidelity to a particular den location. For the purpose of this analysis, we describe den site fidelity as any free-roaming northern pine snake that returned to the same winter den location, two-years in a row. It is not clear, in fact poorly understood, why some pine snakes shift to different dens from one winter to the next. Den shifting has also been observed at other study sites in the New Jersey Pine Barrens (Burger and Zappalorti 2011).

Fidelity to natural overwintering sites among the radio-tracked snakes was observed to be strongest with respect to large abandoned mammal burrows (Carpenter 1953 and 1982, Gregory 1984, Burger et al, 1988, and Burger and Zappalorti 2011). **Figure 55** depicts the fidelity shown to a certain den type (i.e. large mammal burrow, stump hole, etc.) on a multi-year basis. Radio-tracking has shown that large mammal burrows are the most frequently used natural den type by the study snakes. In fact, it is the only den type that a pine snake has shown fidelity to over the entire first five years of the study. The only other den type that has shown snake fidelity for a period longer than two years are the artificial dens in the management fields. Over the past four years two radio-tracked pine snakes have selected and hibernated in the artificial dens every winter (**Table 6**). Dens that have been identified as small mammal burrows or stump holes have thus far only shown snake fidelity for two years at the most.

Figure 56 shows percentage of den type where a pine snake has been recorded spending one winter and then not returning in any of the following years. Interestingly, large mammal burrows also make up the greatest percentage of den types used by radio-tracked snakes for one year and then abandoned.



Figure 54. A small mammal burrow that has been used by a study snake to overwinter in. Photo by Dave Schneider, HA Staff.

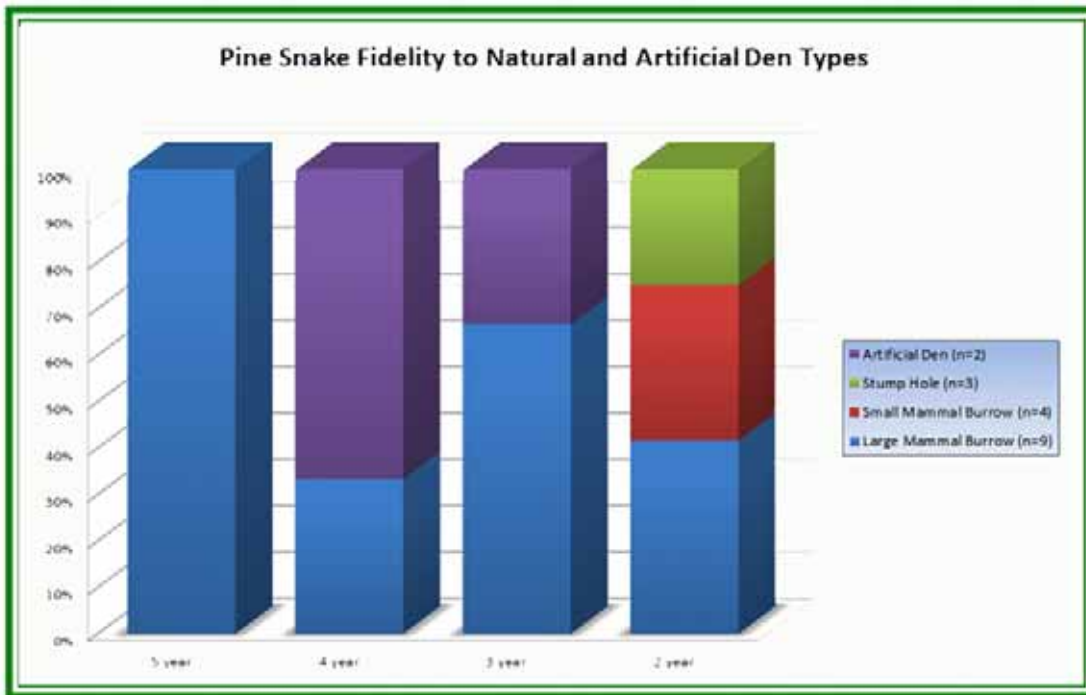


Figure 55. Chart depicting pine snake fidelity to specific den types for multiple years.

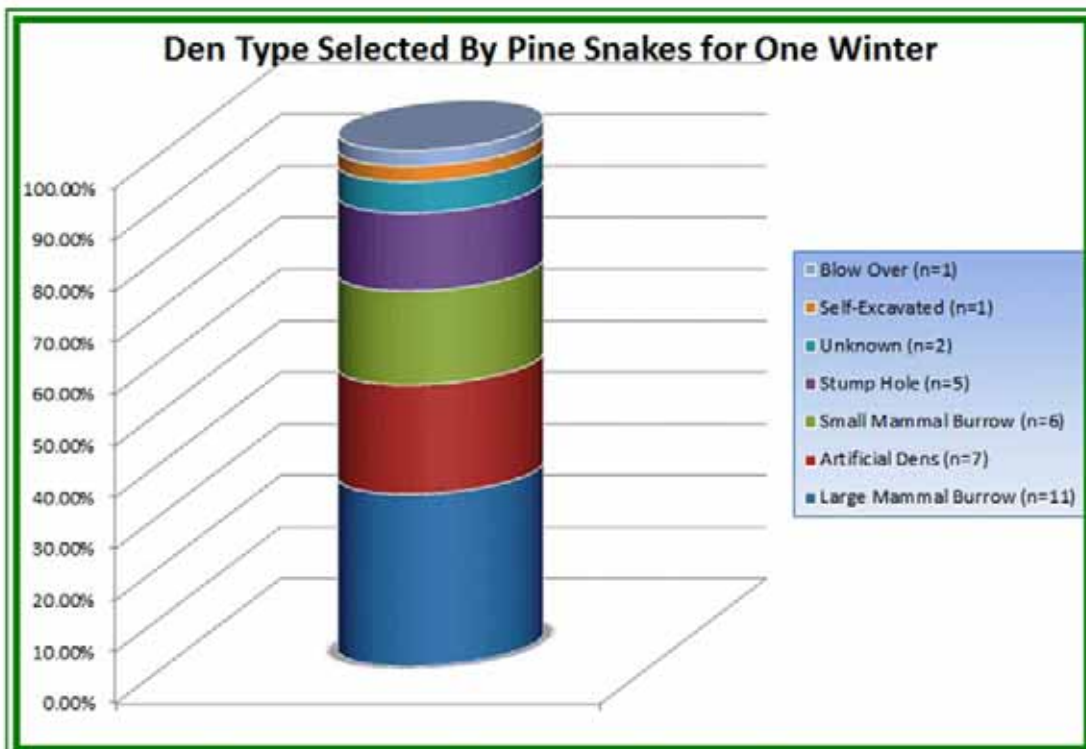


Figure 56. Chart depicting percentage of den type in which a radio-tracked snake has been recorded overwintering for one year and returning to that den location in following years.

Table 6. Pine Snake Fidelity to Natural Hibernacula between 2007 and 2011, a ♣ = Snakes Returning to the Same Den, and ➔ = Snakes Shifting to a Different Den.

Snake ID	2007-2008 Winter	2008-2009 Winter	2009-2010 Winter	2010-2011 Winter	2011-2012 Winter
2006.08	HA Lab	NH 2♣	NH 2 ♣	NH 2 ♣	n/a
2006.09	NH 9	NH 9♣	n/a	n/a	n/a
2006.11	NH 1	NH 17 ➔	n/a	n/a	n/a
2006.16	AH 1(Forced)	AH 1♣	AH 1 ♣	AH 1 ♣	AH 1 ♣
2006.17	AH 6 (Forced)	NH 2 ➔	n/a	n/a	n/a
2006.19	AH 1(Forced)	AH 1♣	AH 1 ♣	AH 1 ♣	AH 2 ➔
2006.21	NH 11	NH 18 ➔	n/a	n/a	n/a
2006.26	NH 1	NH 14 ➔	NH 14 ♣	n/a	n/a
2006.28	AH 1 (Forced)	NH 19 ➔	NH 30 ➔	n/a	n/a
2006.29	AH 6 (Forced)	NH 20 ➔	NH 20 ♣	NH 36 ➔	n/a
2006.32	NH 4	NH 23 ➔	NH 32 ➔	n/a	n/a
2006.34	NH 15	NH 22 ➔	NH 34 ➔	NH 37 ➔	NH 41 ➔
2006.49	AH 1	AH 1 ♣	n/a	AH 1 ♣	NH 42 ➔
2006.108	AH 3	n/a	n/a	NH 5	NH 27 ➔
2007.03	NH 2	NH 2 ♣	n/a	n/a	n/a
2007.04	NH 12	NH 21 ➔	n/a	n/a	n/a
2007.05	NH 14	NH 14 ♣	NH 14 ♣	n/a	n/a
2007.07	NH 3	NH 3 ♣	NH 33 ➔	NH 38 ➔	NH 33 ➔
2007.09	NH 6	NH 25♣	NH 25 ♣	NH 39 ➔	NH 39 ♣
2007.10	NH 10	NH 26 ➔	NH 35 ➔	NH 31 ➔	NH 43 ➔
2007.11	NH 8	NH 8 ♣	NH 8 ♣	NH 8 ♣	NH 8 ♣
2007.14	NH 7	NH 27 ➔	NH 29 ➔	NH 8 ➔	NH 44 ➔
2007.15	NH 13	NH 24 ➔	n/a	n/a	n/a
2008.02	n/a	NH 3 ♣	NH 3 ♣	HA Lab	n/a
2008.03	n/a	NH 5 ♣	NH 5 ♣	NH 5 ♣	NH 45 ➔
2009.13	n/a	n/a	NH 31 ➔	NH 40 ➔	NH 40 ♣

Note: N/A means a snake was lost from the study by predation, road kill or died during hibernation.

BREEDING AND NESTING OBSERVATIONS

Radio-Tracked Female Nesting Behavior

Nesting activities were observed in June and early July of 2011. Only one of the radio-tracked female snakes became gravid in 2011. This was female pine snake 2008.03. It was recorded mating on two occasions. The first observation occurred on 05/11/2011, when it was relocated mating with an unknown male pine snake. The second observation occurred on 05/16/2011, when HA staff recorded the female mating with a male study snake (pine snake 2006.108), approximately 25 meters from the edge of Gray's Road. After the breeding observation, the snake remained in the same area of the pine forest where it was seen mating. This female snake was also gravid in 2009, and nested in the area known as the "Stafford Triangle" (refer to **Appendix IV** for frequently referenced landmarks). However, in 2011 this snake did not return to the "Stafford Triangle" to deposit her eggs. It remained in the upland pine forest and nested in a small natural clearing in the forest (Burger and Zappalorti 2011). Most of the ground cover in the general area of the nest location was a thick layer of pine needles and dead leaves. However, the location of the nest was in a small clearing in the forest measuring 13 meters in diameter. Instead of a thick duff layer, the clearing consisted mostly of loose sand interspersed with golden heather. The snake was found in the nest chamber on 06/09/2011 and remained in it for the next four days.

General Nesting Behavior

Although, we did not note any nests or gravid females in the management fields in 2011, HA staff did find hatchlings in the fields in the late summer and early fall. As previously mentioned, a hatchling was discovered under a cover board in the management fields in mid-September and five additional neonate pine snakes were found in the artificial den traps in the fall. The capture of these hatchlings strongly suggests that at least one non-radiotracked female pine snake nested in the management fields in 2011. Although HA staff never observed any nests in the management fields, the berms are full of small chambers where a snake could have successfully deposited its eggs.

Previously in 2010, female pine snake 2006.29 breached the drift fence that surrounds the SPR site and successfully laid her eggs on the landfill. This snake had also been found on the landfill during the nesting season in the years prior to 2010. Unfortunately, this snake never egressed from its den in the spring of 2011, so it is not known if it would have attempted to nest on the landfill again this year or in future years. HA staff did conduct intensive surveys on the SPR property for nests in early June, but none were observed.

As previously mentioned, in prior years, HA staff has observed nesting at the "Stafford Triangle." In 2011 HA staff surveyed the "Stafford Triangle" on several occasions during the nesting season. On 06/13/2011 staff noted a nest at the same location where one had been excavated in 2009 and 2010. Also, a gravid female was observed basking next to NH 8 on the same day. In prior years hatchlings and eggs had been found in the vicinity of NH 8 and it was assumed this female was going to nest within the den or nearby. Both locations were corralled to capture any emerging hatchlings from the nests for the study being conducted by students from Drexel University. A total of 24 hatchlings were captured at these nests.

There was one other nesting observation in 2011. On 06/11/2011 a female pine snake was observed building a nest along the edge of Gray's Road in the Stafford Forge WMA. Portions of the road have small sandy berms less than a half meter in height lining the sides of it. The snake was observed digging in the berm from a staff vehicle. When the staff member got out to investigate, the snake retreated into the surrounding vegetation. HA noted the size of the sand fan and the excavation opening and left the area as to not disturb the snake any further. The next day staff returned to the site and the sand fan was quite larger than the day before, suggesting the snake had returned to continue excavating the nest. This nest was not corralled due to it's location along the edge of a well traveled dirt road. HA did not want to bring unneeded attention to the nest's location.

Female Breeding Observations

Through intensive monitoring, HA once again observed courtship, mating and nesting behavior of individual pine snakes within the study population in 2011 (**Figure 57**). Although this behavior is rarely witnessed in the wild, radio-tracking has made it possible to observe the mating habits of pine snakes. **Table 7** details every breeding observation witnessed by HA staff from 2007 through 2011. It is interesting to note from the information in the table that many of the snakes appear to breed with the same snake partner year after year. It is our hypothesis that these snakes not only find each other by olfactory scent trailing, but have also learned where and when potential mates can be found within their combined summer home ranges. **Table 7** provides some scientific evidence of this male - female mate selection behavior.



Figure 57. Another close up shot of study snakes 2008.03 and 2009.13 in copulation. Although, HA has observed certain study snakes continuously breed together over the duration of the study , this is the first year these two snakes were recorded mating with each other. Photo by David Burkett, HA staff.

Table 7. Courtship and Breeding Observations of Pine Snakes between 2007 and 2011.

Snake ID	2007	2008	2009	2010	2011
2006.19 (Female)	None observed	None observed	None observed	Recorded breeding with Pine Snakes 2006.16, 2006.108, and unknown male.	None Observed
2006.29 (Female)	None observed	None observed	Recorded breeding with Pine Snake 2007.10.	Recorded breeding with Pine Snake 2007.10.	N/A
2006.34 (Male)	Observed basking next to a stump hole that Pine Snake 2007.05 was concealed in.	None observed, but noted in close proximity to 2007.05 during the breeding season.	Recorded breeding with Pine Snake 2007.05.	Recorded breeding with Pine Snake 2008.13 and with an unknown female.	None Observed
2006.108 (Male)	N/A	N/A	N/A	Recorded breeding with Pine Snake 2006.19.	None Observed
2007.04 (Female)	N/A	None observed.	Observed being scent trailed, but was not observed breeding. However, it did become gravid.	N/A	N/A
2007.05 (Female)	Discovered in a stump hole next to male Pine Snake 2006.34 during the known breeding season.	Recorded breeding with Pine Snake 2008.12 and observed within a few meters of Pine Snake 2006.34.	Recorded breeding with Pine Snake 2006.34 and observed within a few meters of Pine Snake 2008.12 .	None observed.	N/A
2007.07 (Female)	N/A	None observed.	Never observed breeding, but became gravid.	Recorded breeding with Pine Snake 2007.10.	None Observed
2007.10 (Male)	N /A	None observed.	Recorded breeding with Pine Snake 2006.29.	Recorded breeding with Pine Snakes 2006.29 and 2007.07.	None Observed
2007.11 (Male)	N/A	None observed.	None observed.	Observed in courtship behavior with Pine Snake 2007.07.	None Observed
2007.14 (Male)	N/A	None observed.	Recorded breeding with an unknown female.	None observed.	Observed breeding with an unknown female.
2007.15 (Female)	N/A	None observed.	Seen a few feet of Pine Snake 2006.17 during the breeding season. Snake not gravid.	N/A	N/A
2008.03 (Female)	N/A	N/A	Scent trailed by Snakes 2008.08 and 2009.15 on two occasions. Mated with 2009.15.	Recorded being courted by males 2008.08 and 2009.15. Snake was not gravid.	Observed breeding with male 2009.13 and an unknown male.
2009.13 (Male)	N/A	N/A	None Observed.	None Observed.	Observed breeding with female 2008.03.

DISCUSSION AND PRELIMINARY CONCLUSIONS

USE OF ENHANCED OR MANIPULATED HABITAT

With native grass seed provided by Walters, the Department's Division of Land Management planted the three management fields with warm-season grasses on June 1, 2008. The Division drill-seeded the grasses into the mineral soil with only minimal amounts of lime and fertilizer. During the 2008 and 2009 summer seasons the growth of the grasses (and other vegetation) was slow, but steady. Warm-season grasses often take three or four growing seasons to fully establish themselves. These plants use all their energy by growing deep tap-roots into the sandy soil for the first two-years. Once the roots are deep enough then the grasses grow upward on the surface (McCormick 1970 and 1979, Boyd 1991). During the past two years the grasses have begun to thrive, providing ground cover and shelter not only for pine snakes, but for other wildlife as well (HA staff, personal observations). Also, as the grasses and other vegetation becomes more established it produces a rich seed stock for small mammals, birds and reptiles. Managed open fields provide canopy free habitat for snake thermoregulation, potential nesting areas and also attract seed eating small mammals and birds, which are potential prey items for the pine snake population (Zappalorti and Burger 1985, Dodd 1993, Dodd and Seigel 1991, Burger and Zappalorti 2011). The Department's Division of Land Management will mow the three management fields in February 2012, to keep the grasses and other vegetation in an early succession stage (McCormick 1970 and 1979, Boyd 1991).

The earth berms (sand and logs) that surround the management fields provide the snakes with plenty of shelter when they are opaque. It is likely that the berms trap in moisture which makes the shedding process easier for the snakes. Preliminary data collected during the first five years has shown that several of the study snakes have used the management fields on a fairly regular basis for all behavioral needs. HA has recorded snakes nesting, breeding, hibernating, shedding, foraging and sheltering in the management fields throughout the course of the study (Zappalorti et al 2007, 2008, 2009 and 2010). Besides pine snakes, HA has also recorded numerous other reptile and amphibian species in the management fields (**Figure 58**).



Figure 58. Eastern hognose snake. Photo by David Burkett, HA Staff.

PINE SNAKE MORTALITY

Since 2006, HA has witnessed a number of mortalities among the study snakes during the course of this investigation (refer to **Appendix II** for the Deceased Snake Synopses). Pine snakes have always had many natural predators, including raptors, foxes, raccoons, and other small mammals. However, a new threat to the pine snake has only become a recent resident of New Jersey and this is the eastern coyote. The eastern coyote has seen its population expand in the state from 100 animals just forty years ago to over 3,000 (Burnett 2002). HA staff has seen lots of evidence of coyotes throughout the Stafford Forge WMA, from visual sightings to tracks along trails and in the management fields (**Figure 59**). Previously in 2010, a staff member was confident he had observed a coyote feeding on a pine snake alongside Hay Road. In 2011, a coyote was twice seen along the borders of the management fields by a member of the HA staff. One of the sightings occurred not too long after one of the study snakes disappeared while returning to its den in the pine forest directly behind MF 3. Whether the increase in the coyote population is having, or will have, a significant impact on the pine snake populations in New Jersey is unknown, but it is another predator that will feed on the snakes if the opportunity arises.

In addition to the mortalities suffered by the adult study snakes, HA has not had much success in recapturing hatchling pine snakes found in prior years. HA released 71 hatchlings into the artificial dens in 2006. From 2007 to 2010 HA caught an additional 71 hatchling pine snakes (10 in 2007, 11 in 2008, 40 in 2009 and 10 in 2010) for a total of 142 hatchling pine snakes processed by HA staff over the duration of the study so far. In prior years very few of the marked hatchlings have been recaptured. This held true in 2011, with only two of the 142 marked hatchling snakes being recaptured, despite trapping the artificial dens during both the spring and fall and corralling three of the natural dens. It is unknown why so few hatchlings have been accounted for after their initial processing. It is possible that the mortality rate among young snakes is extremely high. It is also possible that the majority of the hatchlings originally selected dens in locations near where they hatched out (i.e. the management fields and NH 8) for their first winter and once they established home ranges they found other suitable dens within those home ranges.



Figure 59 Coyote tracks found in the management fields. Photo by Bob Hamilton, HA staff.

RESEARCH QUESTIONS AND FUTURE GOALS

As stated in the introduction section of this report, there are six research questions that the Department and HA are attempting to answer as part of this long-term study. After the fifth year, HA has arrived at some possible answers, however, in order to scientifically provide answers they must be supported by a significant data set (which in some cases may take the entire course of the study). Below are some preliminary responses to the six questions after five years of data collection.

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

Answer - Yes. Even though the shifted pine snakes were forced to spend one or two-winters in the artificial dens (following the approved management plan protocol), all of these snakes successfully hibernated in them. The corral walls were removed in the spring of 2008. From the winter of 2008/09 through the winter of 2010/11 HA documented a total of eleven pine snakes of varying age classes (adults, juveniles and hatchlings) successfully overwintering in one, or more, of the six artificial hibernacula. In fact, shifted radio-tracked Pine Snakes 2006.16 and 2006.19 have hibernated in the artificial dens every winter of the study. These snakes have been free to select alternate denning locations each winter since the corral walls were removed, yet have returned to the artificial dens at the end of all the active field seasons. It is clear that these two snakes have recognized the artificial hibernacula as suitable overwintering sites. This winter (2011/12) an additional seven newly identified snakes are hibernating in the artificial dens.

HA has also captured a 2006 hatchling pine snake (2006.41) at AH 1 in multiple years, including this spring, showing that it has successfully imprinted on the den as a hibernaculum. HA will continue to trap the artificial den entrances during the spring egress and fall ingress for the remainder of this investigation in order to further determine if adult and young pine snakes continue to use the artificial dens to overwinter.

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

Answer - Yes. During the 2011 spring emergence, HA once again captured non-shifted pine snakes in the AH traps. Since the corral walls were removed from all the artificial dens in 2008 a total of six non-shifted pine snakes have been recorded overwintering in the artificial dens. There are currently another seven newly identified non-shifted snakes in the artificial dens this current winter. Also, HA captured a young hognose snake during fall ingress this year. In addition, a young hognose had been found beneath a cover board near AH 1 in the fall of 2010, so it is possible it is the same snake. So, not only are non-shifted pine snakes using the dens, but also at least one hognose snake. HA will continue to trap the artificial dens during the spring egress in subsequent years to further supplement our data on this den selection behavior.

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

Answer - Inconclusive. Preliminarily, it appears that during each activity season the non-shifted pine snakes have consistently had larger home ranges than the shifted snakes. This was once again the case in 2011. However, a more in depth analysis will need to be conducted to determine if this difference is statistically significant.

An interesting observation regarding habitat use between the two study groups has been noted during the 2010 and 2011 field seasons in the habitat categories of “ecotone between forest and field” and “ecotone between forest and barren ground.” In 2010 shifted snake’s were recorded in these closely associated habitat types five times as often as non-shifted snakes. In 2011, this increased to eight times as often. These two habitat types are most often found around the management fields on the SPR study site. Without a doubt, the shifted snakes have used the management fields far more regularly then the non-shifted snakes during the study.

Both study groups of snakes are relocated more in upland pitch pine forest, than in any other available habitat type. This was again the case in 2011. No significant behavioral differences were observed between the two study groups in 2011. Probably the biggest discrepancy between the two was in the number of concealed observations.

The shifted snakes were found concealed under vegetation or the duff layer approximately ten percent more often than the non-shifted snakes. However, this was counterbalanced by the fact that non-shifted pine snakes were relocated underground five percent more often than the shifted snakes. Essentially both snake sets were engaging in the same behavior (concealment), with one set doing it more often on the surface and the other study set being found more often below the surface. Significant conclusions (if any), regarding differences in home range sizes, behavioral observations, and habitat preferences between non-shifted and shifted snakes cannot be made until the conclusion of the study. At that time, all the data will be statistically analyzed.

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

Answer - Yes. In every previous year of the study a radio-tracked pine snake has been recorded breaching the perimeter drift fence and entering the SPR property. Most of these snakes have been gravid females, presumably trying to return to their traditional nesting habitat. However, in 2011 no radio-tracked pine snakes were relocated on the landfill or any portions of the cleared SPR property. Also, no non-radiotracked pine snakes were observed on the property either. With the removal of the drift fence it is impossible to tell if any snakes attempted to access the property without actual visual observations.

Unfortunately, it may be impossible to fully answer this question. The fact that the radio-tracked snakes have suffered such a high mortality rate has decreased the sample size as the study has progressed. In fact, all snakes that had been previously recorded on the SPR property are now deceased making it impossible to determine if they would have continued to return.

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

Answer - Preliminary results - inconclusive. This is the fourth winter that all radio-tracked snakes were unrestricted in their movements and had the ability to select their own den locations. There is still not enough data to completely answer this question. Since the 2008-2009 winter (when all corral walls were removed from the artificial dens) five of the “Treatment Snakes” have been documented overwintering in the artificial dens. Of the five snakes, two are adults from the “Treatment C” (Lab Treatment) snakes and three are 2006 hatchlings. The two adults (pine snakes 2006.16 and 2006.19) spent the first winter (2006-2007) in HA’s lab and were introduced into AH 1 in 2007. Although AH 1 was one of the two winter treatment dens, these two snakes were only forced to overwinter in it for one year.

Two of the hatchlings (pine snakes 2006.41 and 2006.49) were introduced into AH 1 (a two winter treatment den) in the fall of 2006, and have returned to this den to overwinter in subsequent years. The other 2006 hatchling (2006.46) was released into AH 3 (a one winter treatment den) in 2006, and was relocated in a trap affixed to AH 5 during the 2009 emergence. As previously mentioned, these two adults have returned to the artificial dens every winter. Preliminary results suggest that it did not matter how many winters the snakes were forced to overwinter in the artificial dens. Once released, the majority of the snakes moved back into natural dens in the surrounding forest.

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

Answer - Yes. In 2008, 2009 and 2010, HA staff observed both shifted and non-shifted gravid female pine snakes using the management fields as nesting habitat. In 2011, as previously mentioned, no radio-tracked pine snakes were observed nesting in the management fields. Likewise, none of the non-radio tracked pine snakes were observed using the fields during the nesting season. However, the capture of neonate pine snakes during the late summer months suggests that at least one unknown pine snake nested somewhere in one of the fields. If a non-radio-tracked snake crawled into one of the perimeter sand mounds and deposited her eggs, HA staff would not be able to detect her presence. HA staff will keep a close watch for gravid female pine snakes during the 2012 nesting season.

SUMMARY

In 2011, HA completed its fifth year of pine snake radio-tracking at the SPR property and the surrounding Stafford Forge WMA. HA continued to record the secretive behavior of pine snakes that is rarely otherwise observed in the wild. These observations included courtship and mating (breeding), foraging for mammal and avian prey, evidence of nesting and egg laying (capturing hatchlings) and winter den selection (overwintering behavior). The continued use of the management fields and artificial dens by both shifted and non-shifted snakes suggests that some free roaming snakes have learned to recognize the fields as suitable nesting, foraging and hibernating habitat. This behavior is likely to continue, based upon similar pine snake and corn snake management and conservation studies HA has made at the Audubon Sanctuary in western Berkeley Township, Ocean County, New Jersey (Frier and Zappalorti 1983, Zappalorti and Reinert 1994, Zappalorti and Golden 2006, and Robert Zappalorti, personal observations).

In 2011, HA witnessed a decline in the number of mortalities among the radio-tracked snakes compared to previous field seasons. No predation of the radio-tracked pine snakes was actually observed during the 2011 field season. However, as previously mentioned one snake did not emerge from hibernation for unknown reasons. The den location it chose appeared suitable, as it was a rather large mammal burrow. The shape and size of the burrow should have enabled the snake to get far enough underground so it would not freeze to death during the winter. HA has found evidence in prior studies of both shrews and skunks entering pine snake dens and feeding upon the dormant snakes (Burger et al., 1992, Robert Zappalorti, personal observations). It's also possible a larger mammal entered the burrow and was able to locate the snake and feed on it. In addition to this snake being lost from the study, one other snake went missing in late October. This snake was moving back towards the den it had used during all the previous years of the study and then simply disappeared.

As a result, there were 12 pine snakes that were actively radio-tracked until the end of the 2011 field season. Although, HA can always supplement the non-shifted study set with newly captured snakes, it is impossible to replace the 2006 cohort of shifted adult snakes. However, there are still three juvenile pine snakes (that were not implanted because they were too small in 2006), that could be recaptured by HA in 2012. A priority has been set to capture these individuals by den trapping and random searching. The surviving hatchlings from the 2006 cohort (see **Table 1**), that were hatched-out in the laboratory and released into the artificial dens could also be studied (Zappalorti and Golden 2006). Nevertheless, the 2006 hatchlings cannot be considered part of the "shifted" study group (since the hatchlings never had the opportunity to establish a home range and therefore cannot be considered shifted). HA suggests that it is extremely important to gain an understanding of the home ranges established by the 2006 hatchlings after being hatched in the laboratory and released into the artificial dens. It is also important to learn if the 2006 hatchlings have imprinted on the management fields, especially in regards to nesting and overwintering behavior (Zappalorti and Golden 2006).

While there are other pine snake studies published in literature such as Kauffeld (1957), Zappalorti et al, (1985), Burger and Zappalorti (1986, 1987, 1988, 1989, 1991 and 1992), Burger et al, (2000), Burger et al, (2007), Himes et al, (2006), Gerald, Bailey and Holmes (2006a and 2006b), Golden et al, (2009) and Burger and Zappalorti (*in press*, 2011), none of these studies compare to this current investigation. The level of effort, the amount of resources and funding that is being provided by Walters, Inc., HA and the NJDEP's Division of Fish and Wildlife is unprecedented. The results of 2007, 2008, 2009, and 2010 have already been submitted, while the 2011 results are contained in this document and submitted herewith. There is much more to be learned over the remainder of the study and HA looks forward to continuing this important research and investigation.

Respectfully submitted,

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Herpetological Associates, Inc.

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Figure 60. HA staff member, David Burkett takes notes during the 2011 field season. Photo by Bob Hamilton, HA staff.

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APPENDICES

APPENDIX I

Appendix I						
Hibernaculum	Field No. of snakes that denned in Hibernaculum (2007-08)	Field No. of snakes that denned in Hibernaculum (2008-09)	Field No. of snakes that denned in Hibernaculum (2009-10)	Field No. of snakes that denned in Hibernaculum (2010-11)	Field No. Of snakes that denned in Hibernaculum (2011-12)	Description of Hibernaculum
AH 1	2006.16, 2006.19, 2006.22, 2006.28	2006.16, 2006.19, 2006.41**, 2006.49**, 2009.12**	2006.16, 2006.19, 2009.12****	2006.16, 2006.19, 2006.49****, 2010.04****, 2011.18****	2006.16, 2011.26****, 2011.30****	Artificial hibernaculum created by Walters using HA's design. Located on south side of MF 1.
AH 2	None Known	2009.09**	None Known	None Known	2006.19	Artificial hibernaculum created by Walters using HA's design. Located on north side of MF 1.
AH 3	None Known	2009.11**	None Known	None Known	None Known	Artificial hibernaculum created by Walters using HA's design. Located on south side of MF 2.
AH 4	2006.15, 2006.30	None Known	None Known	None Known	2011.25****, 2011.28****	Artificial hibernaculum created by Walters using HA's design. Located on north side of MF 2.
AH 5	None Known	2006.46**	None Known	2009.12	None Known	Artificial hibernaculum created by Walters using HA's design. Located on south side of MF 3.
AH 6	2006.17, 2006.29	None Known	2010.01****	None Known	2011.23****, 2011.24****, 2011.27****	Artificial hibernaculum created by Walters using HA's design. Located on north side of MF 3.
NH 1	2006.26, 2006.11	None Known	None Known	None Known	None Known	Small mammal burrow in pine forest approximately 90 meters west of MF 3.

Appendix I (Continued)						
Hibernaculum	Field No. of snakes that denned in Hibernaculum (2007-08)	Field No. of snakes that denned in Hibernaculum (2008-09)	Field No. of snakes that denned in Hibernaculum (2009-10)	Field No. of snakes that denned in Hibernaculum (2010-11)	Field No. Of snakes that denned in Hibernaculum (2011-12)	Description of Hibernaculum
NH 2	2007.03	2007.03, 2006.08, 2006.17	2006.08, 2009.16***	2006.08, 2007.23, 2008.09, 2009.16, 2011.01	None Known	Large mammal burrow in pine forest approximately 70 meters NW of AH 6.
NH 3	2007.07, 2008.02*	2007.07, 2008.02	2008.02	None Known	None Known	Large mammal burrow in upland pine forest in SFWMA west of management fields.
NH 4	2006.32	None Known	None Known	None Known	None Known	Stump hole in lowland oak/pine forest approximately 27 meters SW of Hay Road in SFWMA.
NH 5	2006.33, 2008.03*	2008.03	2008.03	2006.108 2008.03	None Known	Large mammal burrow in upland pine forest in the interior of SFWMA.
NH 6	2007.09	None Known	None Known	None Known	None Known	Small mammal burrow with stump hole complex present in upland pine forest in interior of SFWMA.
NH 7	2007.14, 2008.04*	None Known	None Known	None Known	None Known	Small mammal burrow leading into earth berm in disturbed pine forest habitat approximately 3.0 km S/SW of the SPR site.

Appendix I (Continued)						
Hibernaculum	Field No. of snakes that denned in Hibernaculum (2007-08)	Field No. of snakes that denned in Hibernaculum (2008-09)	Field No. of snakes that denned in Hibernaculum (2009-10)	Field No. of snakes that denned in Hibernaculum (2010-11)	Field No. Of snakes that denned in Hibernaculum (2011-12)	Description of Hibernaculum
NH 8	2007.11	2007.11, 2008.18**, 2008.21**, 2008.25**, 2009.02**, 2009.04**, 2009.05**, 2009.06**, 2009.07**, 2009.08**, two (2) sub-adult northern black racers	2007.11	2007.11, 2007.14, 2009.07*****, 2011.02*****, 2011.03*****, 2011.04*****, 2011.08*****, 2011.09*****, 2011.10*****, 2011.11*****, 2011.13*****, 2011.14*****, 2011.15*****, 2011.16*****, 2011.17*****	2007.11, 2011.29*****	Large mammal burrow in disturbed pine forest approximately 100 meters from NH G.
NH 9	2006.09	2006.09	None Known	None Known	None Known	Stump hole (complex) in upland oak/pine forest approximately 1.1 kilometers N/NW of management fields.
NH 10	2007.10	None Known	None Known	None Known	None Known	Small mammal burrow in upland oak/pine forest approximately 1.7 km north of management fields within SFWMA.
NH 11	2006.21	None Known	None Known	None Known	None Known	Small mammal burrow in upland oak/pine forest on privately owned land approximately 2.4 kilometers north of the management fields.
NH 12	2007.04	None Known	None Known	None Known	None Known	Small mammal burrow at base of a mountain laurel in upland oak/pine forest on privately owned land approximately 15 meters in on west side of route 72.

Appendix I (Continued)						
Hibernaculum	Field No. of snakes that denned in Hibernaculum (2007-08)	Field No. of snakes that denned in Hibernaculum (2008-09)	Field No. of snakes that denned in Hibernaculum (2009-10)	Field No. of snakes that denned in Hibernaculum (2010-11)	Field No. Of snakes that denned in Hibernaculum (2011-12)	Description of Hibernaculum
NH 13	2007.15	None Known	None Known	None Known	None Known	Stump hole in privately owned upland oak/pine forest south of the SPR site.
NH 14	2007.05	2007.05, 2006.26	2006.26	None Known	None Known	Small mammal burrow in upland oak/pine forest south of the SPR site. Not far from NH M.
NH 15	2006..34	None Known	None Known	None Known	None Known	Stump hole in upland oak/pine forest approximately 1.3 km S/SW of the SPR site.
NH 16	2007.06	Not Known	Not Known	Not Known	Not Known	This was an unsuccessful attempt by the snake to excavate its own overwintering spot. Snake's carcass was found only a few inches under the surface in the spring of 2008.
NH 17	None Known	2006.11	None Known	None Known	None Known	Stump hole in a section of pine/oak forest near the Garden State Parkway south of the SPR site.
NH 18	None Known	2006.21	None Known	None Known	None Known	Stump hole in pine/oak forest only a few meters in on west side of Route 72. Location is approximately 3.1 km north of MF 3.
NH 19	None Known	2006.28	None Known	None Known	Not Known	Small mammal burrow in pine/oak forest a considerable distance SW of the SPR site.

Appendix I (Continued)						
Hibernaculum	Field No. of snakes that denned in Hibernaculum (2007-08)	Field No. of snakes that denned in Hibernaculum (2008-09)	Field No. of snakes that denned in Hibernaculum (2009-10)	Field No. of snakes that denned in Hibernaculum (2010-11)	Field No. Of snakes that denned in Hibernaculum (2011-12)	Description of Hibernaculum
NH 20	None Known	2006.29	2006.29, 2009.51***	None Known	None Known	Stump hole in upland pine forest west of the management fields.
NH 21	None Known	2007.04	None Known	None Known	None Known	Stump hole on slight upland rise in pine/oak forest approximately 2.25 kilometers north of the management fields and 0.4 kilometers west of Route 72.
NH 22	None Known	2006.34	None Known	None Known	None Known	Small mammal burrow in oak/pine forest south of the SPR site. Multiple stump holes as well as NH 15 nearby – part of complex of refugia.
NH 23	None Known	2006.32	None Known	None Known	None Known	Den is located in unburned upland oak/pine forest approximately six meters in on north side of Hay Road. There was no noticeable entrance hole to den location due to large amount of leaf litter on the forest floor.
NH 24	None Known	2007.15	None Known	None Known	None Known	Mammal burrow approx. 160 meters south of the drift fence along the southern portion of the SBR site near the Costco building.
NH 25	None Known	2007.09	2007.09	None Known	None Known	Stump hole located on private property near the Brighton Road Development Property on west side of Route 72. Location is approximately 4.4 km NW of the management fields.

Appendix I (Continued)						
Hibernaculum	Field No. of snakes that denned in Hibernaculum (2007-08)	Field No. of snakes that denned in Hibernaculum (2008-09)	Field No. of snakes that denned in Hibernaculum (2009-10)	Field No. of snakes that denned in Hibernaculum (2010-11)	Field No. Of snakes that denned in Hibernaculum (2011-12)	Description of Hibernaculum
NH 26	None Known	2007.10	None Known	None Known	None Known	Q. alba root system in same tract of upland oak/pine forest that the snake hibernated in last year.
NH 27	None Known	2007.14	None Known	None Known	2006.108	Large hunter's pit/mammal burrow in upland pine forest approximately 1.6 km SW of MF 1.
NH 28	None Known	None Known	2007.14	None Known	None Known	Large mammal burrow
NH 29	None Known	None Known	2007.05	None Known	None Known	Stump hole in pine/oak forest south of the SPR site near the Garden State Parkway.
NH 30	None Known	None Known	2006.28	None Known	None Known	Root system of old white oak in oak/pine forest south of the SPR site.
NH 31	None Known	None Known	2009.13	2007.10	None Known	Small mammal burrow in oak/pine forest approx. 1.3 km NW of the management fields.
NH 32	None Known	None Known	2006.32	None Known	None Known	Stump hole in upland pine forest west of Hay Road.
NH 33	None Known	None Known	2007.07	None Known	2007.07	Cluster of small mammal burrows leading underground in oak/pine forest approx. 1.65 kilometers north of the management fields.

Appendix I (Continued)						
Hibernaculum	Field No. of snakes that denned in Hibernaculum (2007-08)	Field No. of snakes that denned in Hibernaculum (2008-09)	Field No. of snakes that denned in Hibernaculum (2009-10)	Field No. of snakes that denned in Hibernaculum (2010-11)	Field No. Of snakes that denned in Hibernaculum (2011-12)	Description of Hibernaculum
NH 34	None Known	None Known	2006.34	None Known	None Known	A nondescript mammal burrow in a pine/oak forest south of the SPR site.
NH 35	None Known	None Known	2007.10	None Known	None Known	Small stump hole in a pine/oak forest south of the SPR site.
NH 36	None Known	None Known	None Known	2006.29	None Known	Large mammal burrow.
NH 37	None Known	None Known	None Known	2006.34	None Known	Stump hole in upland oak/pine forest south/southeast of the management fields.
NH 38	None Known	None Known	None Known	2007.07	None Known	Base of a half-fallen pitch pine.
NH 39	None Known	None Known	None Known	2007.09, 2010.06****, 2011.05****, 2011.06****, 2011.07****, 2011.09****, 2011.12****, 2011.19****	2007.09	Large mammal burrow.
NH 40	None Known	None Known	None Known	2009.13	2009.13	Small mammal burrow.
NH 41	None Known	None Known	None Known	None Known	2006.34	Small mammal burrow.
NH 42	None Known	None Known	None Known	None Known	2006.49	Medium sized mammal burrow.
NH 43	None Known	None Known	None Known	None Known	2007.10	Non-descript hole.
NH 44	None Known	None Known	None Known	None Known	2007.14	Medium size mammal burrow.
NH 45	None Known	None Known	None Known	None Known	2008.03	Non-descript hole.
* Denotes a non-radiotracked snake that was captured in a trap attached to a corralled den in the spring of 2008.						
** Denotes a non-radiotracked snake that was captured in a trap attached to a corralled den in the spring of 2009.						
*** Denotes a non-radiotracked snake that was found basking at a known natural den entrance in the fall of 2009.						
****Denotes a non-radiotracked snake found trapped or basking at a known den in the spring or fall of 2010.						
*****Denotes a s non-radiotracked snake found trapped or basking at a known den in the spring or fall of 2011.						

APPENDIX II

Appendix II. Deceased Study Snake Synopses:

Shifted Snakes

1) *N. Pine Snake No. 2006.06* (♂). (Treatment B/2 winter) Deceased in 2007.

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

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

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

3) *N. Pine Snake No. 2006.09* (♀). (Shifted Snake, Treatment A/1 winter) Deceased in 2009.

This snake was originally captured during a presence/absence survey conducted by EcolSciences, Inc. in 2004. On 11/04/09, this snake was observed basking near a stump hole approximately 20 meters north of NH I. The snake was observed to be alert and was actively tongue flicking despite the cool ambient temperature (13.6 degrees C). It was assumed that it would once again overwinter within NH I. When HA staff later attempted to confirm that the snake was actually within NH I, no signal could be detected in the immediate vicinity. A concerted effort was made to locate the snake from several points within its known home range, and despite the use of three receiver boxes, no signal was received and the snake was not found. It is thought that the snake was carried off by a hawk or mammal predator since no transmitter signal was ever again detected, and no carcass was found

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

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

5) *N. Pine Snake No. 2006.11* (♂). (Shifted Snake, Treatment A/1 winter) Deceased in 2009.

This snake was originally caught by EcolSciences, Inc. on the landfill access road on 05/17/06. On 05/20/09 this snake was found killed by an unknown predator along the edge of a wetland corridor west of its previous relocation. The snake had been decapitated and a portion of the upper body was missing. Based on the condition of the carcass (i.e., the cleanly severed backbone and

tissue at the wound, rather than stripping of the flesh) suggest mammalian predation. It appeared to have been a recent mortality, since there was no odor emanating from the carcass and rigor mortis had not set in yet. It is possible that the predator that was responsible was scared off by the approach of HA staff before it could finish eating the snake. Because there were just 15 relocations for this snake in 2009, a home range map is not shown.

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

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

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

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

8) *N. Pine Snake No. 2006.15* (♂). (Shifted Snake, Treatment C/Lab) Current status = Undetermined.

This snake was captured in trap 24 along the perimeter drift fence by EcolSciences, Inc. on 05/17/06. According to the transmitter signal, pine snake 2006.15 never egressed from the large earthen mound in MF 2 where it hibernated during the 2008 - 2009 winter. Whether this snake failed to successfully overwinter, or the radio-transmitter fell off is not known. This snake was fitted with an external transmitter towards the end of the 2008 field season and it is possible that the radio- transmitter may have slipped-off during the winter or during spring egress. Attempts by HA staff to dig-up and unearth this transmitter were unsuccessful.

9) *N. Pine Snake No. 2006.17* (♂). (Treatment C/Lab) Deceased in 2009.

This snake was captured by EcolSciences, Inc. on 05/21/06 in trap eighteen (18) along the perimeter drift fence. On 05/20/09 this snake was found dead on the road (DOR), on the edge of the Garden State Parkway's southbound lane. The dead pine snake was seen by an HA staff member in a passing vehicle. He went back to inspect the snake and found its non-functional transmitter popped-out of the body, thus confirming its identity.

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

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

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

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

12) N. Pine Snake No. 2006.21 (♀). (Treatment A/1 winter) Deceased in 2009.

This snake was originally captured in trap 95 along the perimeter drift fence by EcolSciences, Inc. on 05/27/06. On 04/23/09, this snake was discovered in an active defensive posture (coiled in a striking position and hissing) and bleeding profusely from its eye and snout. An active red squirrel (*Tamiasciurus hudsonicus*) feeding station and burrow was noted within 1 meter of the snake. It is likely that the snake was attempting to shelter in the burrow, as the ambient temperature was 14.5 degrees C. It is probable that the snake was too cool to feed or defend itself adequately and received a serious bite from the red squirrel. Though outwardly healthy and in good body weight upon egress from hibernation, the snake went into a slow decline after suffering this serious facial injury. Pine snake 2006.21 moved a few hundred meters southeast from its location on 4/23/09 into upland oak/pine forest approximately 180 meters SW of Route 72, and remained in this general area throughout the season. This snake eventually became blind in its right eye, developed a mouth infection, and continued to lose weight as the season progressed. On 10/21/09, the snake was found killed by an unknown small predator, possibly a fox or raccoon. The snake's head and neck were missing, and the posterior third of the body was eviscerated with the transmitter exposed. The carcass was collected and frozen by HA staff.

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

This snake was originally captured by EcolSciences, Inc. in trap 95 along the perimeter drift fence on 05/27/06. This snake was released into AH 1, a two winter treatment, on 09/22/06 where it spent the 2006-07 winter. In April, 2008 this snake was observed to be breathing irregularly. The animal was taken to a veterinarian where it died. The exact cause of death is unknown, but the necropsy revealed a white chalky substance surrounding the heart, possibly indicative of gout.

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

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

15) N. Pine Snake No. 2006.26 (♂). (Shifted Snake, Treatment A/1 Winter) Current status = Undetermined/Lost.

This snake was originally captured by EcolSciences, Inc. during the summer of 2006. Beginning in the middle of May 2010 HA staff were unable to pick up the signal from this snake's transmitter despite repeated efforts throughout the remainder of the field season. HA had a similar problem with pine snake 2006.28 (see synopsis for 2006.28 for further details regarding that snake's current status) which was using the same area of forest during the same time period.

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

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

17) N. Pine Snake No. 2006.28 (♀). (Shifted Snake, Treatment C/Lab) Current status = Deceased.

This snake was initially captured by HA on the landfill on 06/23/06. On 05/22/10, this snake made a large northern move towards the edge of the old landfill parcel. As mentioned in the synopsis for pine snake 2006.26, this snake's transmitter signal was subsequently lost. It was not until 07/13/10 that HA staff relocated pine snake number 2006.28's radio-transmitter. It was found on a vegetated island in the middle of a wetland corridor. The antenna wire on the radio-transmitter was chewed or snapped off. There were no scales, bones, or remnants of the snake's carcass and was probably eaten.

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

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

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

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

20) N. Pine Snake No. 2006.32 (♀). (Shifted Snake, Treatment A/1 winter) Current status = Deceased.

This snake was originally captured in trap 61 along the perimeter drift fence on 07/08/06. It is not certain when this snake egressed from NH 32, where it overwintered because most of the study snakes came out of hibernation earlier than normal due to an unusually warm Spring. When the snake was checked on 04/15/10, HA only found the radio-transmitter on the ground surface within a couple of meters from the den. Because of the physical evidence found at the scene, HA is confident that a raptor had killed the snake. It is likely that when it emerged from its den to bask during a warm spell, that a raptor, such as a red-tailed hawk attacked, killed and ate the specimen.

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

This snake was originally captured in trap 5 along the perimeter drift fence by EcolSciences, Inc. on 08/11/06. This animal was implanted with a transmitter and released into AH 5, a one winter treatment, on 09/22/06, where it hibernated in the 2006-07 winter. In March 2008 this snake was observed on the surface near the entrance hole of NH E, when HA staff were preparing to corral the denning site. The ambient air temperature was at or near 0 degrees Celsius at the time. HA decided that this animal was behaving in a manner that would result in its death, so it was collected to be observed by a veterinarian. The animal died in the HA field trailer on 03/24/08. The carcass has been frozen and retained for further analysis.

22) N. Pine Snake No. 2006.41 (♂) (A Laboratory Hatched Snake, Released into Treatment A/1 Winter) Current status = Deceased.

This snake was from a 2006 clutch laid by Pine snake 2006.09 in HA's laboratory. It was hatched out and released into AH 1 in the fall of 2006. On 08/14/10 this snake was found deceased hanging from a tree branch approximately fifteen feet up in a pitch pine tree. HA staff was able to retrieve part of the snake's carcass, in which the anterior one third of the snake was missing. Based on the amount of whitewash that was present at the base of the pine tree, it is highly suspected that raptor predation was the cause of its death.

Non-Shifted Snakes

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

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

2) N. Pine Snake No. 2007.04 (♀). Deceased in 2009.

This snake was originally captured by HA staff on 05/25/07 in an isolated section of disturbed pine/oak forest on the east side of the Stafford Park construction site. On 08/14/09, HA staff

discovered the partially eaten body. It was a few meters in the forest, killed by an unknown predator. Upon recovery of the transmitter, HA staff observed that the antenna wire was ripped from the transmitter casing and was twisted and damaged. Based upon past observations HA suspects a red-tailed hawk was the predator.

3) N Pine Snake 2007.05 (♀). Current status = Undetermined.

This snake was originally captured by HA staff on 05/28/07 emerging from a stump hole next to pine snake 2006.34, during a radio-tracking relocation south of the construction site. On 06/19/10, HA staff was unable to pick up a signal from the snake's transmitter. Despite repeated efforts throughout the remainder of the field season HA staff was not able to relocate this snake. It is unknown what happened to cause the transmitter signal to be lost. It is interesting to note that the snake was lost in the same tract of forest where a researcher had the encounter with a coyote when radio-tracking this snake earlier in the season. At the beginning of the field season one study snake was found predated upon and another went missing in the same section of forest this snake disappeared in. It's possible that coyote or red fox are preying upon HA's study snakes in this area of the forest.

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

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

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

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

This large male snake was originally captured by HA staff in a heavily burnt pine forest on 6/04/07 during a random search effort. When captured, the snake had visible burns and scars on portions of its body. It was implanted with a transmitter on 07/19/07 and released the following day. On 08/01/07 this snake was relocated within 15 meters of a residential property in the village of Warren Grove, Ocean County, New Jersey. From 08/03/07 until 09/04/07 this snake was consistently relocated in either open field or disturbed habitat, including the front lawn of a private residence. All of the property was situated along the east side of Route 539 in the village of Warren Grove. On 09/04/07 this snake was found dead on Route 539 in Warren Grove by an HA staff member.

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

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

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

7) N. Pine Snake 2007.13 (♀). Deceased in 2007.

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

8) N. Pine Snake 2007.15 (♀). Deceased in 2009.

This snake was originally captured in trap 8 on 08/17/07 along the perimeter drift fence on the south side of the SPR property.

On 10/21/09 this snake's transmitter was found on the forest floor approximately 260 meters northwest of its 2008 overwintering location. The markings on the transmitter wire suggested that the snake was likely killed by a raptor because the wire had tear marks in it. Additional evidence that a hawk killed the snake was observed in the form of a quantity of "whitewash" (white uric acid from a raptor) on the trunk of a pine tree and shrubs. No additional remains of this snake were recovered by HA staff, with the exception of the above mentioned transmitter.

APPENDIX III

Appendix III Hatchling Snakes Recaptured Since Initial Release Into Artificial Hibernacula in September 2006.					
HA Field Number	Recaptured in 2007	Recaptured in 2008	Recaptured in 2009	Recaptured in 2010	Recaptured in 2011
2006.36	Yes (In AH 6 trap during spring egress)	No	No	No	No
2006.37	No	No	No	No	No
2006.38	No	No	No	No	No
2006.39	No	No	No	No	No
2006.40	Yes (In AH 1 trap during spring egress)	No	No	No	No
2006.41	Yes (In AH 1 trap during spring egress)	No	Yes (In AH 1 trap during spring egress)	Yes (Found crossing Slocum Road approximately 800 meters southwest of the management fields. It was implanted with a one year transmitter. Killed by a raptor in 2010.)	Died in 2010
2006.42	Yes (In AH 5 trap during spring egress)	No	No	No	No
2006.43	No	No	No	No	No
2006.44	Yes (In AH 5 trap during spring egress)	No	No	No	No
2006.45	No	No	No	No	No

Appendix III (Continued)					
HA Field Number	Recaptured in 2007	Recaptured in 2008	Recaptured in 2009	Recaptured in 2010	Recaptured in 2011
2006.46	No	Yes	Yes (In AH 3 trap during spring egress)	No	No
2006.47	Yes (In AH 1 trap during spring egress)	No	No	No	No
2006.48	Yes (Under cover board near AH 2)	No	No	No	No
2006.49	No	Yes (Crawling along perimeter drift fence near trap 55)	Yes (On top of AH 1 on 04/25/09)	No	Yes. (Snake was found in a trap attached to an artificial den 1 trap. Has been added to the radio-tracking study)
2006.50	No	No	No	No	No
2006.51	No	No	No	No	No
2006.52	Yes (In AH 2 trap during spring egress)	No	No	No	No
2006.53	Yes (In AH 3 trap during spring egress)	No	No	No	No
2006.54	No	No	No	No	No
2006.55	No	No	No	No	No
2006.56	No	No	No	No	No

Appendix III (Continued)					
HA Field Number	Recaptured in 2007	Recaptured in 2008	Recaptured in 2009	Recaptured in 2010	Recaptured in 2011
2006.57	No	No	No	No	No
2006.58	Yes (Found dead in the AH 1 outer corral after the May 2007 forest fire)	N/A	N/A	N/A	N/A
2006.59	No	No	No	No	No
2006.60	No	No	No	No	No
2006.61	No	No	No	No	No
2006.62	No	No	No	No	No
2006.63	Yes (In AH 2 trap during spring egress)	No	No	No	No
2006.64	Yes (In AH 3 trap during spring egress)	No	No	No	No
2006.65	Yes (Found dead near AH 3. Cause unknown.)	N/A	N/A	No	No
2006.66	No	No	No	No	No
2006.67	No	No	No	No	No
2006.68	No	No	No	No	No
2006.69	No	No	No	No	No

Appendix III (Continued)					
HA Field Number	Recaptured in 2007	Recaptured in 2008	Recaptured in 2009	Recaptured in 2010	Recaptured in 2011
2006.70	Yes (In the inner corral of AH 6)	No	No	No	No
2006.71	No	No	No	No	No
2006.72	Yes (In AH 1 trap during spring egress)	No	No	No	No
2006.73	Yes (In AH 2 trap during spring egress)	No	No	No	No
2006.74	Yes (In AH 2 trap during spring egress)	No	No	No	No
2006.75	No	No	No	No	No
2006.76	No	No	No	No	No
2006.77	Yes (In AH 2 trap during spring egress)	No	No	No	No
2006.78	Yes (In AH 1 trap during spring egress)	No	No	No	No
2006.79	Yes (In AH 5 trap during spring egress)	No	No	No	No

Appendix III (Continued)					
HA Field Number	Recaptured in 2007	Recaptured in 2008	Recaptured in 2009	Recaptured in 2010	Recaptured in 2011
2006.80	No	No	No	No	No
2006.81	No	No	No	No	No
2006.82	Yes (In AH 2 inner corral)	No	No	No	No
2006.83	Yes (In AH 5 trap during spring egress)	No	No	No	No
2006.84	No	No	No	No	No
2006.85	No	No	No	No	No
2006.86	Yes (In AH 5 trap during spring egress)	No	No	No	No
2006.87	Yes (In AH 2 trap during spring egress)	No	No	No	No
2006.88	No	No	No	No	No
2006.89	Yes (In AH 5 trap during spring egress)	No	No	No	No
2006.90	No	No	No	No	No
2006.91	Yes (In AH 5 trap during spring egress)	No	No	No	No

Appendix III (Continued)					
HA Field Number	Recaptured in 2007	Recaptured in 2008	Recaptured in 2009	Recaptured in 2010	Recaptured in 2011
2006.92	No	No	No	No	No
2006.93	No	No	No	No	No
2006.94	No	No	No	No	No
2006.95	Yes AH 3 trap in spring	No	No	No	No
2006.96	Yes (AH 4 inner corral)	No	No	No	No
2006.97	No	No	No	No	No
2006.98	Yes (AH 6 trap in spring)	No	No	No	No
2006.99	No	No	No	No	No
2006.100	No	No	No	No	No
2006.101	No	No	No	No	No
2006.102	No	No	No	No	No
2006.103	No	No	No	No	No
2006.104	Yes (Near AH 3)	No	No	No	No
2006.105	Yes (Near AH 5)	No	No	No	No
2006.106	Yes (Near AH 1)	No	No	No	No

APPENDIX IV

APPENDIX IV: LANDMARK DESCRIPTIONS FOR MAP LEGEND

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

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

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

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

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

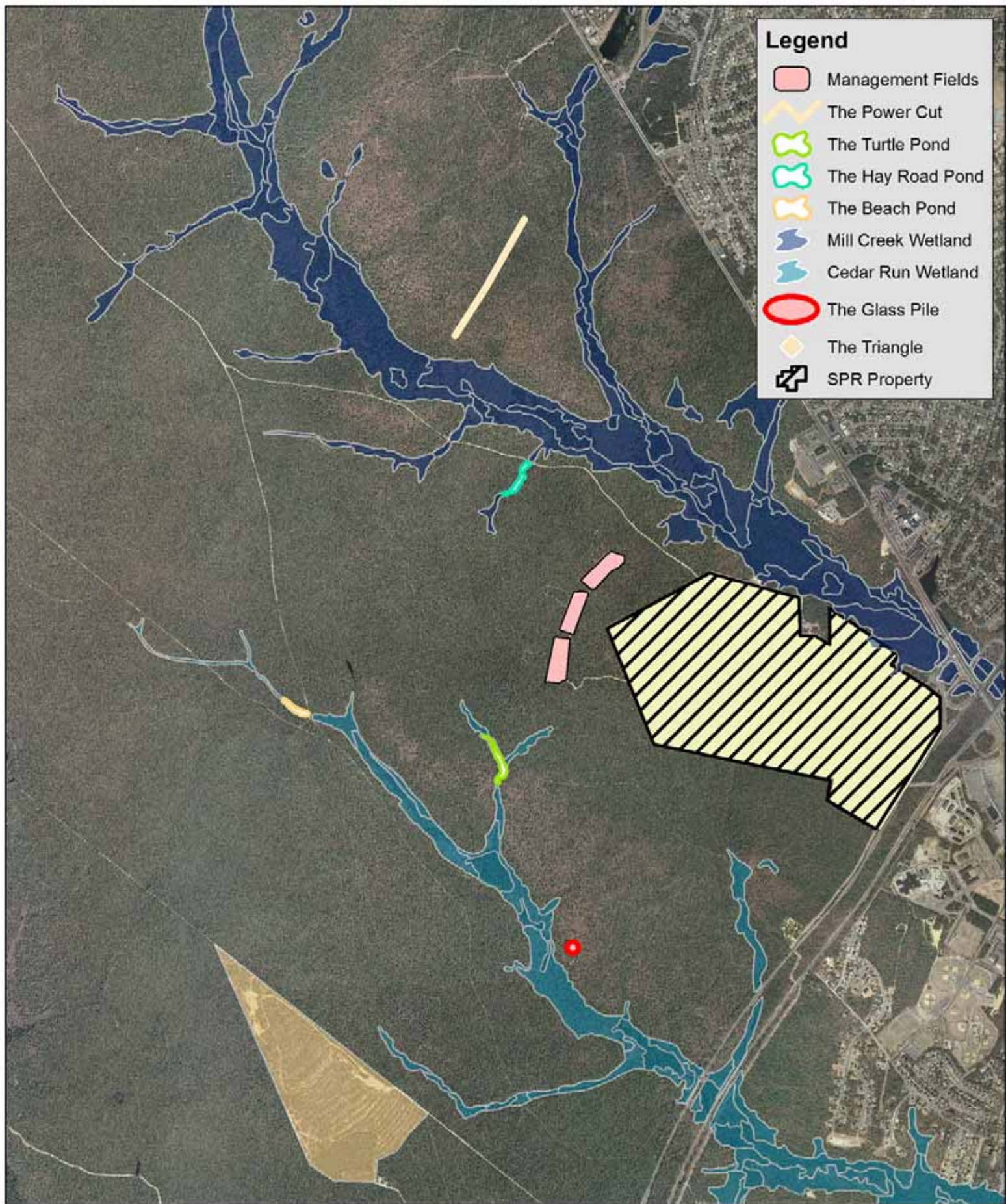
6. Beach Pond: A small body of water located west of the SPR site, referenced by the open sandy shore along its eastern edge.

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

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

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

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



Appendix IV. Frequently referenced landmarks in Stafford Forge WMA

Source Image: 2007 NJGIN Orthophotography

Herpetological Associates, Inc. 2010

0 250 500 1,000 1,500 2,000
Meters

