

HA File No. NJ2006.19-A

***2010 Annual Northern Pine Snake Monitoring and Radio-tracking  
Report, at the Stafford Business Park, Stafford Township,  
Ocean County, New Jersey***



*Submitted January 31, 2011*

*To*

***The Walters Group***

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

*By*

**Robert Zappalorti, David Burkett, Robert Hamilton and Matthew McCort**

***Herpetological Associates, Inc.***

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

*and*

**Dave Golden, Principal Zoologist**

***Division of Fish and Wildlife***

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

❁ TABLE OF CONTENTS ❁

**Introduction.** . . . . . 1

**Background Information.** . . . . . 1

**Materials and Methods.** . . . . . 3

    HA Staff and Researchers. . . . . 3

    Creation of Management Fields and Artificial Dens. . . . . 3

    Onsite Monitoring. . . . . 5

    Habitat Evaluation. . . . . 5

    Reptile and Amphibian Survey Techniques. . . . . 6 - 8

    Protocol for Releasing Trapped Snakes. . . . . 9

    Radio-telemetry. . . . . 9 - 11

**Results of the 2010 Investigation.** . . . . . 12

    Description of Existing Conditions and Habitats. . . . . 12 - 13

    Reptile and Amphibian Surveys . . . . . 13 - 14

    Drift Fence Survey Results for 2010. . . . . 15 - 16

    Results of Radio-tracking. . . . . 16 - 17

    Individual Snake Synopses and Home Range Maps. . . . . 18 - 53

    Habitat Use and Behavioral Analysis. . . . . 54 - 57

    Three Experimental Snake Treatments. . . . . 58 - 59

        Treatment “A” Snakes (One-Winter). . . . . 58

        Treatment “B” Snakes (Two-Winter). . . . . 59

        Treatment “C” Snakes (One Winter in HA Lab). . . . . 59

    Non-Shifted Pine Snakes. . . . . 59 - 60

    Juvenile and Hatchling Pine Snakes. . . . . 60 - 65

    Use of Manipulated and Enhanced Habitat. . . . . 66 - 68

    Environmental Inspections and Monitoring. . . . . 68 - 69

    Foraging and Feeding Observations. . . . . 69 - 72

    Winter and Summer Den Use. . . . . 73 - 75

    Pine Snake Fidelity to Winter Dens. . . . . 75 - 77

    Breeding and Nesting Observations. . . . . 78 - 82

**Discussion and Preliminary Conclusions.** . . . . . 83

    Use of Enhanced or Manipulated Habitat. . . . . 83

    Prey Availability for Pine Snakes. . . . . 84

    Predation of Pine Snakes. . . . . 85

    Research Questions & Future Goals. . . . . 86 - 88

**Summary.** . . . . . 89 - 90

**Acknowledgments.** . . . . . 91

**Literature Cited.** . . . . . 92

**List of Tables**

Table 1. Reptile and Amphibian Captured by Random Searching.. . . . . 14  
Table 2. Reptile and Amphibian Species Captured in Perimeter Drift Fence.. . . . . 15  
Table 3. MCP and Kernal Home Range Analysis Data for 2010. . . . . 17  
Table 4. Habitat Preferences of Radio-tracked Snakes in 2010. . . . . 57  
Table 5. Foraging and Feeding Observations of Pine Snakes in 2010. . . . . 72  
Table 6. Pine Snake Fidelity to Winter Dens from 2007 to 2010.. . . . . 77  
Table 7. Courtship and Breeding Observations of Pine Snakes between 2007-2010.. . . 80  
Table 8. 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. . . . . 89

**List of Figures**

Fig. 1. Aerial map of Stafford Business Park. . . . . 2  
Fig. 2. Layout of Pine Snake Management Fields, Artificial Dens and Fences. . . . . 4  
Fig. 3. Perimeter Drift Fence with Snake Trap. . . . . 7  
Fig. 4. Hognose Snake in Trap . . . . . 8  
Fig. 5. Black Racer Snake in Trap. . . . . 8  
Fig. 6. Dave Burkett Radio-tracking Pine Snake. . . . . 10  
Fig. 7. Pine Snake in Dead Tree. . . . . 11  
Fig. 8. Selectively Cut Forest off Hay Road. . . . . 12  
Fig. 9. Ringneck Snake.. . . . . 13  
Fig. 10. Rough Green Snake. . . . . 13  
Fig. 11. Map of radio-telemetry locations and activity range for 2006.08 . . . . . 19  
Fig. 12. Mating Pine Snakes. . . . . 20  
Fig. 13. Map of radio-telemetry locations and activity range for 2006.16.. . . . . 21  
Fig. 14. Photo of Study Snake 2006.19, Basking.. . . . . 22  
Fig. 15. Map of radio-telemetry locations and activity range for 2006.19.. . . . . 23  
Fig. 16. Photo of Red Fox - Predator of Pine Snakes. . . . . 24  
Fig. 17. Warm Season Grasses on Management Field One.. . . . . 25  
Fig. 18. Nesting Site of Female 2006.29, on SPR Property.. . . . . 26  
Fig. 19. Map of radio-telemetry locations and activity range for 2006.29.. . . . . 27  
Fig. 20. Red-tailed Hawk in Tree.. . . . . 28  
Fig. 21. Map of radio-telemetry locations and activity range for 2006.34. . . . . 30  
Fig. 22. Map of radio-telemetry locations and activity range for 2006.41. . . . . 32  
Fig. 23. Map of radio-telemetry locations and activity range for 2006.28. . . . . 34  
Fig. 24. Pine Snake 2007.05, Eating Cottontail Rabbit Pups. . . . . 35  
Fig. 25. Map of radio-telemetry locations and activity range for 2007.05.. . . . . 36  
Fig. 26. Female 2007.07, Hissing in Defensive Coil. . . . . 37  
Fig. 27. Map of radio-telemetry locations and activity range for 2007.07.. . . . . 38  
Fig. 28. Male Pine Snake 2007.09, Coiled Basking. . . . . 39  
Fig. 29. Map of radio-telemetry locations and activity range for 2007.09.. . . . . 40  
Fig. 30. Two Radio-tracked Study Snakes Mating. . . . . 41  
Fig. 31. Map of radio-telemetry locations and activity range for 2007.10.. . . . . 42  
Fig. 32. Male Pine Snake 2007.11, Drinking Water. . . . . 43  
Fig. 33. Map of radio-telemetry locations and activity range for 2007.10.. . . . . 45

Fig. 34. Map of radio-telemetry locations and activity range for 2007.14..... 47

Fig. 35. Male Pine Snake 2008.02, Basking at Den, but in Poor Health..... 48

Fig. 36. Map of radio-telemetry locations and activity range for 2008.02..... 49

Fig. 37. Map of radio-telemetry locations and activity range for 2008.03..... 51

Fig. 38. Male 2009.13 basking next to a fallen log..... 52

Fig. 39. Map of radio-telemetry locations and activity range for 2009.13..... 53

Fig. 40. Chart comparing percentages of habitat preferences in 2010..... 55

Fig. 41. Chart depicting 2009 behavioral observations..... 56

Fig. 42. Matt McCort searching for Pine Snake nests on MF 2..... 61

Fig. 43. Pine Snake Nest..... 62

Fig. 44. Matt McCort holding a gravid female Pine Snake..... 63

Fig. 45. Female Pine Snake laying her eggs in a nest chamber..... 64

Fig. 46. Hatchling Pine Snake and another Pine Snake hatching out..... 65

Fig. 47. Michael Zappalorti releasing a Pine Snake captured next to AH 1..... 67

Fig. 48. Southern gray treefrog breeding pond (Retention Basin D)..... 69

Fig. 49. Meadow jumping mouse caught in perimeter drift fence..... 70

Fig. 50. Two masked shrews caught in the perimeter drift fence..... 70

Fig. 51. White footed mouse..... 70

Fig. 52. Juvenile eastern cottontail rabbit..... 71

Fig. 53. Pine Snake after it attacked a dove’s nest..... 72

Fig. 54. Chart depicting den type selection among radio-tracked pine snakes..... 73

Fig. 55. Snake trap attached to the entrance of an artificial den..... 74

Fig. 56. Chart depicting den type fidelity among radio-tracked pine snakes..... 75

Fig. 57. Diagrammatic drawing of a natural Pine Snake hibernaculum..... 78

Fig. 58. Two Pine Snakes mating..... 81

Fig. 59. View of perimeter drift fence showing regrowth of forest vegetation..... 82

Fig. 60. Warm season native grasses growing on the management fields..... 83

Fig. 61. Pine Snake swallowing an eastern mole..... 84

Fig. 62. Red-tailed hawk..... 85

Fig. 63. Northern red salamander..... 90

Fig. 64. Redbelly snake..... 90

Fig. 65. Eastern kingsnake constricting and killing an eastern garter snake..... 91

**Appendices..... 101**

Appendix I. Hibernacula Table..... 102 - 110

Appendix II. Deceased Snake Synopses..... 111 - 118

Appendix III. 2006 Hatchling Table..... 119 - 125

Appendix IV. Landmark Reference..... 126 - 128

## INTRODUCTION

This is the fourth annual northern pine snake (*Pituophis m. melanoleucus*) progress report with respect to the on-going 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 (see **Figure 1**). Providing a framework for this project, is the June 28, 2006 Memorandum of Agreement (hereafter MOA) which was made between Walters Homes, Inc. (hereafter Walters), Stafford Township, and the New Jersey Pinelands Commission (hereafter the Commission). As part of its responsibilities, 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 Mill Creek. Walters created three pine snake habitat management fields, containing six artificial winter snake hibernacula (hereafter dens); shifted a portion of the population of pine snakes; and initiated a seven-year pine snake monitoring program. Walters has already begun residential and commercial development of the SPR property.

## BACKGROUND INFORMATION

Threatened and endangered species surveys commenced at the SPR property in April 2004. These surveys, which were conducted by EcolSciences, Inc., revealed the presence of three state-listed species, including the northern pine snake. The northern pine snake is listed as a state-threatened species in New Jersey by the Department of Environmental Protection, and it occurs on and in the vicinity of the SPR property. Considerable effort was put forth surveying the SPR property site for pine snakes during the 2004, 2005 and 2006 activity seasons. In May of 2006, Herpetological Associates, Inc. (hereafter HA) was asked to assist with the ongoing research. Through these intensive surveys, it was found that the SPR property was providing critical foraging, nesting, and overwintering habitat for northern pine snakes (**Figure 1**). It was determined that pine snakes on the SPR property required a long-term management and conservation study plan.

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

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





**Figure 1.** A 2007 aerial photograph showing a western view of the study site and the early stages of the commercial construction on the eastern and central portions of the site. The licensed landfill is centered on the western portion of the SPR property (highlighted with white lines), and retention basin D is located in the extreme western portion of the site (highlighted in white). The three pine snake mitigation and management fields are due west from the edge of the site (outlined in red lines), and the perimeter exclusion drift fence and traps (also outlined with red lines) that surrounded the SPR property. Source: Walters, Inc.

The seven-year, long-term monitoring program will evaluate whether the pine snakes shifted from the old landfill at the Stafford Business Park will use and exploit the newly created artificial dens and management fields. 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 Researchers

There were numerous tasks to be performed and data to be collected during the 2010 field season at the SPR property. The following HA staff members were present during some, or all of the plant and wildlife monitoring or surveys: David Burkett, Dave Emma, Robert Hamilton, William Callaghan, Joe Embrey, Raymond Farrell, Robert Fengya, Ted Gordon, Zigmund Leszczynski, Matthew McCort, Pete Mooney, David Schneider, Michael Zappalorti and Robert Zappalorti. Additionally, Dave Golden also advised and assisted with various tasks throughout the 2010 field season.

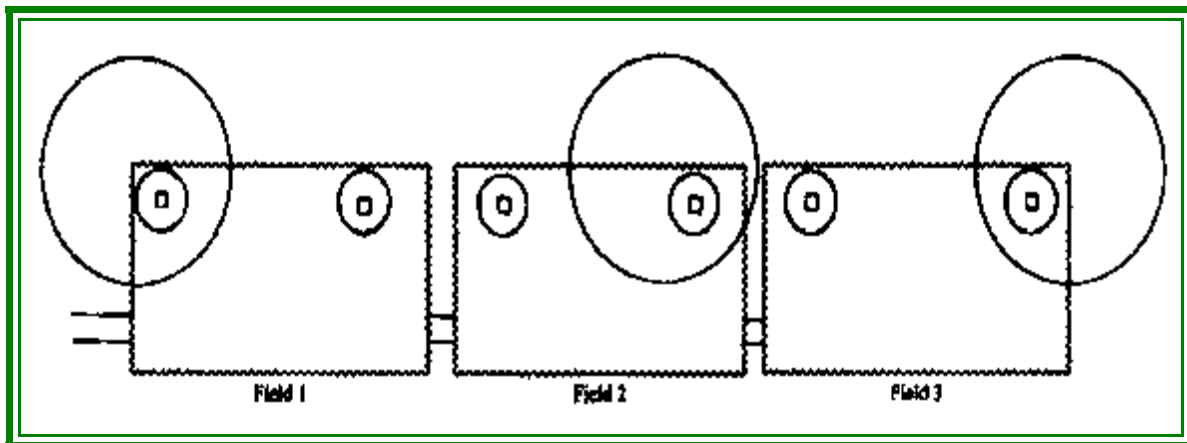
### CREATION OF MANAGEMENT FIELDS AND ARTIFICIAL DENS

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 **Figure 2**).

These three 5.5-acre fields were meant to replace the open grassland habitat that was lost on the SPR site (*e.g.*, the 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). 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 - see **Table 7**).

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 lab treatment) was not originally planned, but was created out of necessity after it was determined that 8 of the pine snakes were not healthy enough to be released in the fall of 2006. Because of the eight snake's poor health, unlike Treatments A and B, they 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 and 2010 activity seasons.

Another portion of the relocation and management phase of the conservation plan involved enhancing existing habitat within SF 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.



**Figure 2.** Original layout of the Northern Pine Snake Management Fields, showing the artificial hibernacula and former locations of the temporary corral fences at Stafford Forge WMA, in 2006-2007. In 2008 the corral walls were removed from around all artificial hibernacula. Only the fields and artificial dens remain in 2010.

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

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



After emerging from the artificial dens, snakes in the two-winter treatments were all released into the 3-acre corrals (see **Figure 2**). On May 16, 2007, a severe forest fire devastated the entire pine snake study area and the three management fields, burning all the fabric off the fences and all the vegetative cover in the forest. Due to the lack of vegetative cover, complications from hawk predation and damage related to the May 16, 2007 forest fire, 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.

## **ONSITE MONITORING**

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

## **HABITAT EVALUATION**

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

- 1. Structure of Available Habitat:** Both the biotic and abiotic components are considered. These are good indicators for the possible occurrence of particular ETR species within a specific study area (Burger and Zappalorti 1986; Reinert and Zappalorti 1988a and 1988b; and Heyer et al. 1994).
- 2. Historic Evidence:** Known sightings of the target ETR species in the State Natural Heritage Program database, and historic records on or in the vicinity of a study site, are important to the overall evaluation of a site as habitat for ETR species (Zappalorti and Johnson 1982, Golden and Jenkins 2003, Golden et al. 2009).
- 3. Indicator Species:** The presence of plant and animal species that are often found in association with a target ETR species is highly informative when evaluating the suitability of a study site. Such indicator species may include food/prey organisms, or species that typically occur in similar or identical habitats as the target ETR species. The presence of associated or indicator species demonstrates the ecological value of the habitat within a particular study site (Frier and Zappalorti 1983, Brown 1993, Kingsbury and Gibson 2002).

## **REPTILE AND AMPHIBIAN SURVEY TECHNIQUES**

Reptiles and amphibians are often difficult to census due to their highly secretive nature and ability to remain hidden for long periods of time. Environmental conditions such as ambient temperature, precipitation, soil moisture, relative humidity, light intensity, wind, and season have strong influences on reptile and amphibian activity patterns (Vogt and Hine 1982). Unsuitable weather conditions may lead to increased fossorial behavior (burrowing), markedly reduced activity, shifts in habitat usage, and/or estivation (dormancy during hot and dry conditions) (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).



**Figure 3.** A box-funnel trap attached to the perimeter drift fence that surrounded the SPR property between 2006 and 2010. These traps not only captured Pine Snakes, but numerous other reptiles, amphibians and small mammals. The perimeter drift fence also helped keep wildlife off the construction areas and provided HA with a species list for a wildlife inventory. Photo by Bob Zappalorti, HA.

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

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

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

One large perimeter drift fence, totaling approximately 13,000 feet, has 126 box funnel traps associated with it, was erected around 90% of the study site and has been in operation since April 15, 2006 (**Figure 1**). The fence traverses various habitat types in an attempt to capture free-ranging pine snakes (**Figure 3**). 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).





**Figure 4.** An Eastern Hognose Snake captured in one of the Drift Fence Traps. Photo by Mike Zappalorti, HA Staff.

Each box trap measured approximately three feet long, one foot high and one foot wide (see **Figures 3, 4 and 5**). The traps were constructed from treated plywood and 1/4 inch mesh galvanized hardware cloth. Each trap had one plastic funnel placed with its wide end attached to the end of the trap, and the narrow end extending into the trap. A hinged lid with latches allowed easy access to 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 perimeter drift fence was also meant to exclude pine snakes and other species from entering the SPR property. The drift fence was constructed of black nylon silt fence, 3-feet in height, and was supported with oak stakes. Approximately 5 to 8-inches of the fence material was buried below grade level, thereby preventing snakes and other wildlife from crawling under the fence (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).



**Figure 5.** An adult Northern Black Racer caught in a funnel trap. Photo by Bob Zappalorti, HA.



## **PROTOCOL FOR RELEASING TRAPPED PINE SNAKES FOUND IN 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.

Radio-tracked pine snakes caught in the drift fence traps or found along the perimeter drift fence were moved approximately 200 meters, into the Stafford Forge WMA forest, roughly perpendicular to their point of capture at the drift fence. Snakes new to the study were processed (weighed, measured and sexed), PIT tagged (Elbin and Burger 1994), and then released according to the same procedure followed for radio-tracked specimens. Unlike in previous years, snakes that had somehow breached the perimeter drift fence and were relocated on the SPR property, were not shifted back into Stafford Forge WMA. One of the questions in this study addresses whether pine snakes that were shifted in 2006 from the landfill into Stafford Forge WMA would continue to try to access the landfill in the following years, especially females during the nesting season (Burger and Zappalorti 1986 and 1991). Since there was no active construction occurring on the landfill in 2010, HA staff felt that it was important, for data purposes, to allow any pine snakes that chose to enter the landfill to move about unmolested. This will continue to be HA'S protocol for the continuation 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 and 2010 were conducted by qualified HA staff members in HA's laboratory in Jackson, New Jersey. Any future surgical implantation of study snakes will be conducted by a qualified HA staff member (e.g., Bob Zappalorti, Mike Torocco, Matt McCort and/or Dave Schneider).

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



**Figure 6.** HA staff member, Dave Burkett radio-tracking one of the shifted Pine Snakes on Stafford Forge WMA. A concerted effort was made to relocate each Pine Snake with a radio-transmitter every 48-hours. Photograph by Bernd Skubowius.

### ***Transmitter Surgeries in 2010***

All snake surgeries were completed before August 15, 2010 (Lutterschmidt 1994, Rudolph et al, 1998). Snakes that had their old transmitters replaced in 2008 were once again due for new transmitters in 2010. A total of seven pine snakes were pulled from the field for transmitter re-implantation surgery during the 2010 field season. After transmitter removal, HA staff assessed the overall health of each snake. Time frames for snake re-implantation and eventual release varied with the condition of each specimen.

Authorized HA staff conducted all transmitter removal and implantation surgeries. All seven snakes successfully had their old transmitters removed and replaced. In addition to the snakes that needed replacement transmitters, two other pine snakes (pine snakes 2006.41 and 2006.108) were implanted with transmitters for the first time in 2010 (please refer to the Individual Snake Synopsis for details about these two snakes).

### ***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 ArcView 3.2 (Environmental Systems Research Institute, ESRI, Inc., 1992-1999) and activity range maps/calculations were done with the Animal Movement Program 2.0 (Tufto et al, 1996, Hooge et al. 1997, USGS, Alaska Biological Science Center).



**Figure 7.** Radio-tracked Pine Snake 2008.03, coming down from a standing dead oak tree. It was thought the snake raided a red squirrel nest in the hollow tree trunk. Photo by Bernd Skubowius.

### ***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 uses least squares for cross validation (Silverman 1986) for the smoothing parameter (H). 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 2010 radio-telemetry data.

## RESULTS OF THE 2010 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 addition to the habitat alteration that has occurred on the SPR site, the NJ Forest Fire Service initiated an extensive tree-thinning effort within the Stafford Forge WMA (which borders a majority of the SPR site) in 2009 (**Figure 8**).



**Figure 8.** A Southwestern view of the selectively cut pine and oak forest south of Hay Road. Tree thinning was done by the New Jersey Division of Parks and Forest in the Spring of 2009. Photo by Bob Hamilton, HA Staff.





**Figure 9.** A juvenile Southern Ringneck Snake that was found under a fallen log. Photo by Mike Zappalorti, HA Staff.

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). It is unknown what effects (if any) the tree clearing process will have upon the local pine snake population, but HA believes there will be no adverse impact. In fact, the tree thinning will most likely benefit the pine snakes by increasing rodent populations (additional prey animals), providing more open basking opportunities and cover from the log and brush piles that were created at HA's request.

## REPTILE AND AMPHIBIAN SURVEYS

### *Visual Survey Results*

In 2010, random searching and visual surveys resulted in the observation, capture and identification of 21 different reptile and amphibian species in and around the SPR property and the adjacent Stafford Forge WMA. **Table 1** lists the 21 assorted species captured or observed during the 2010 field season. Several snake species were found while conducting radio-tracking monitoring of pine snakes, such as ring-necked snake, red-bellied snake, rough green snake, hognose snake and black racer snake (**Figures 9 and 10**).



**Figure 10.** Close-up of a Rough Green Snake basking on an oak branch by Mill Creek. Photo by Bob Zappalorti, HA.

**Table 1. Reptile and Amphibian Species Captured or Observed in and around the SPR Property and the adjacent Stafford Forge WMA in 2010.**

| Species Number | 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              | Northern Redbelly Snake             | <i>(Storeria o. occipitomaculata)</i>      |
| 10             | Rough Green Snake                   | <i>(Opheodrys aestivus)</i>                |
| 11             | Eastern Hognose Snake               | <i>(Heterodon platirhinos)</i>             |
| 12             | Northern Black Racer                | <i>(Coluber c. constrictor)</i>            |
| 13             | Northern Pine Snake                 | <i>(Pituophis m. melanoleucus)</i>         |
| 14             | Fowler's Toad                       | <i>(Anaxyrus fowleri)</i>                  |
| 15             | Northern Spring Peeper (Vocalizing) | <i>(Pseudacris c. crucifer)</i>            |
| 16             | Pine Barrens Treefrog (Vocalizing)  | <i>(Hyla andersonii)</i>                   |
| 17             | Southern Gray Treefrog (Vocalizing) | <i>(Hyla chrysoscelis)</i>                 |
| 18             | Southern Leopard Frog               | <i>(Lithobates sphenoccephalus)</i>        |
| 19             | Green Frog                          | <i>(Lithobates clamitans melanota)</i>     |
| 20             | Bullfrog                            | <i>(Lithobates catesbeiana)</i>            |
| 21             | Carpenter Frog (Vocalizing)         | <i>(Lithobates virgatipes)</i>             |

Some of the species listed above in **Table 1** were either seen by HA staff while radio-tracking, heard calling during spring breeding choruses (frogs and toads), or found alive or dead on roads. Likewise, small mammals and birds were also seen and heard while conducting routine field work or checking traps. Several pine snake feeding observations were made while conducting routine radio-tracking studies as well.

### ***Drift Fence Survey Results for 2010***

In 2010 HA staff followed the same protocol for the drift fence study as in prior years. Traps were opened on April 15, 2010 and were checked within a 48 hour time period throughout the active field season. There were **126** snake funnel traps placed along the approximately 13,000 feet of drift fence. As in previous years of this study, the traps were closed for the winter on October 31, 2010. The purpose of the perimeter drift fence was to prevent northern pine snakes (and other small wildlife), from entering the SPR property and construction areas. The perimeter drift fence also helped stop and capture any other species of snakes, turtles, frogs and toads trying to enter the SPR property. During the course of the 2010 field season, 19 species of reptiles and amphibians were found in the various drift fence traps. **Table 2** lists the confirmed species that were trapped.

**Table 2. Reptile and Amphibian Species Captured or Observed in the Perimeter Drift Fence Trapping System Around the SPR Property in 2010** (\* Species only found by Trapping)

| <b>Species Number</b> | <b>Common Name</b>           | <b>Scientific Name</b>                     |
|-----------------------|------------------------------|--|
| 1                     | Eastern Box Turtle           | <i>(Terrapene c. carolina)</i>             |
| 2                     | Eastern Painted Turtle       | <i>(Chrysemys p. picta)</i>                |
| 3                     | Northern Fence Lizard        | <i>(Sceloporus undulatus hyacinthinus)</i> |
| 4                     | Northern Redbelly Snake      | <i>(Storeria o. occipitamaculata)</i>      |
| 5                     | Eastern Garter Snake         | <i>(Thamnophis s. sirtalis)</i>            |
| 6                     | Eastern Ribbon Snake         | <i>(Thamnophis s. sauritus)</i>            |
| 7                     | Eastern Worm Snake           | <i>(Carphophis a. amoenus)</i>             |
| 8                     | Rough Green Snake            | <i>(Opheodrys aestivus)</i>                |
| 9                     | Eastern Hognose Snake        | <i>(Heterodon platirhinos)</i>             |
| 10                    | Northern Black Racer         | <i>(Coluber c. constrictor)</i>            |
| 11                    | Northern Pine Snake          | <i>(Pituophis m. melanoleucus)</i>         |
| 12                    | *Eastern Kingsnake           | <i>(Lampropeltis g. getula)</i>            |
| 13                    | *Northern Redback Salamander | <i>(Plethodon cinereus)</i>                |
| 14                    | *Northern Red Salamander     | <i>(Pseudotriton r. ruber)</i>             |
| 15                    | Fowler's Toad                | <i>(Anaxyrus fowleri)</i>                  |
| 16                    | Northern Spring Peeper       | <i>(Pseudacris c. crucifer)</i>            |
| 17                    | Southern Gray Treefrog       | <i>(Hyla chrysoscelis)</i>                 |
| 18                    | Coastal Plain Leopard Frog   | <i>(Lithobates utricularia)</i>            |
| 19                    | Green Frog                   | <i>(Lithobates clamitans melanota)</i>     |

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

### ***Artificial and Natural Den Designations***

As a result of our intensive radio-tracking studies, HA discovered a large number of natural pine snake dens over the past four field seasons. In 2010, 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). All natural dens located each previous year and in the 2010 field season are designated as “Natural Hibernacula” (NH 1 through 40). **Appendix I** shows each individually designated hibernacula and the corresponding snakes that utilized them in the 2007, 2008, 2009 and 2010 field seasons. The 2007 - 2008 winter was the last winter that snakes were forcibly held within the two-winter treatments (AH 1, AH 4, and AH 6), thus completing the experimental habitat imprinting portion of the study. Since spring 2008, all study snakes have been free-roaming. Therefore, all overwintering sites used by radio-tracked snakes in the 2010 - 2011 winter season were selected by the snakes, without any influence from HA researchers, as they had unrestricted access to their natural winter den locations.

### **RESULTS OF RADIO-TRACKING**

In 2010, a total of 19 pine snakes were radio-tracked throughout the active field season (April through October). This number includes 8 original “shifted snakes”, 9 “non-shifted” snakes captured in the past and two recaptured pine snakes (Field Numbers 2006.41 and 2006.108), which were implanted with transmitters for the first time in 2010. Pine snake 2006.41 (a male) was one of the hatchlings from the eggs collected in 2006 that were hatched out in HA’s laboratory and released into the artificial dens. Even though this snake has a 2006 field number, it cannot be considered part of the 2006 shifted snake data set. The reason is that the snake was released directly into AH 1 after hatching out, and therefore, had never established a home range from which to be shifted. However, HA believes that radio-tracking any 2006 hatchlings that are recaptured will provide important data to the study. Pine snake 2006.108 (also a male) was a young three year snake captured in the perimeter drift fence in 2006. It was too small at the time to be implanted with a transmitter, so it was just PIT tagged and released into AH 3. HA does include this snake in the shifted snakes data set, since the snake had likely established a semblance of a home range before being trapped in the perimeter drift fence and “shifted” into AH 3. So, of the nine shifted radio-tracked pine snakes tracked by HA at the start of 2010, six snakes (3 males and 3 females) remain alive and healthy, two are deceased (both females), and one male is currently unaccounted for. Of the nine non-shifted snakes radio-tracked in 2010, eight are alive and healthy (6 males and 2 females) and one female is currently unaccounted for (please refer to the Individual Snake Synopses). The 2006 hatchling (2006.41) is deceased.



**Radio-telemetry Monitoring**

Radio-tracked pine snakes were relocated between 31 and 69 times in 2010. **Figures 40 and 41** show a comparison of the habitat selected and behaviors of the shifted versus non-shifted snakes. **Table 3** shows the Minimum Convex Polygon 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). A brief synopsis of every adult pine snake involved in the radio-telemetry aspect of this project during the 2010 field season, whether currently alive or deceased, is detailed below. **Appendix II** at the end of the report provides a brief synopsis of each snake that has died prior to the 2010 radio-telemetry season. In addition, home range analysis maps of the pine snakes radio-tracked during the 2010 activity season are 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 season.

| <b>Table 3. Minimum Convex Polygon (MCP) in Acres and Hectares and Kernel Activity Range (Both 50% and 90 % Isopleth) Home Range Sizes for 16 Radio-tracked Pine Snakes in 2010.</b> |               |                       |                        |          |                                |          |                                |          |
|--|---------------|-----------------------|------------------------|----------|--------------------------------|----------|--------------------------------|----------|
| 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             | 53                    | 291.40                 | 117.93   | 104.06                         | 42.11    | 449.78                         | 182.02   |
| 2006.16  | M             | 66                    | 302.29                 | 122.33   | 194.91                         | 78.88    | 607.52                         | 245.85   |
| 2006.19  | F             | 55                    | 69.52                  | 28.13    | 66.75                          | 27.01    | 225.73                         | 91.35    |
| 2006.29  | F             | 40                    | 583.95                 | 236.31   | 265.10                         | 107.28   | 874.46                         | 353.88   |
| 2006.34  | M             | 50                    | 311.67                 | 126.13   | 120.47                         | 48.75    | 469.43                         | 189.97   |
| 2006.41  | M             | 32                    | 88.48                  | 35.81    | 87.93                          | 35.58    | 289.48                         | 117.15   |
| 2006.108   | M             | 51                    | 299.60                 | 121.24   | 153.44                         | 62.09    | 517.69                         | 209.50   |
| 2007.05  | F             | 28                    | 55.77                  | 22.57    | 74.80                          | 30.27    | 266.18                         | 107.72   |
| 2007.07  | F             | 59                    | 511.66                 | 207.06   | 196.73                         | 79.61    | 705.02                         | 285.31   |
| 2007.09  | M             | 31                    | 684.12                 | 276.85   | 226.49                         | 91.66    | 719.27                         | 291.08   |
| 2007.10  | M             | 59                    | 201.57                 | 81.57    | 87.56                          | 35.43    | 348.50                         | 141.03   |
| 2007.11  | M             | 69                    | 307.22                 | 124.33   | 174.42                         | 70.59    | 513.68                         | 207.88   |
| 2007.14  | M             | 61                    | 473.34                 | 191.55   | 182.45                         | 73.83    | 638.18                         | 258.26   |
| 2008.02  | M             | 33                    | 1104.99                | 447.17   | 250.53                         | 101.39   | 1007.61                        | 407.77   |
| 2008.03  | F             | 59                    | 350.31                 | 141.76   | 133.93                         | 54.20    | 502.24                         | 203.25   |
| 2009.13  | M             | 55                    | 114.81                 | 46.46    | 107.22                         | 43.39    | 353.17                         | 142.92   |
| <b>N=16</b>  | <b>6m:10f</b> |                       |                        |          |                                |          |                                |          |

## INDIVIDUAL SNAKE SYNOPSES AND HOME RANGE MAPS

### ABOUT THE HOME RANGE MAPS

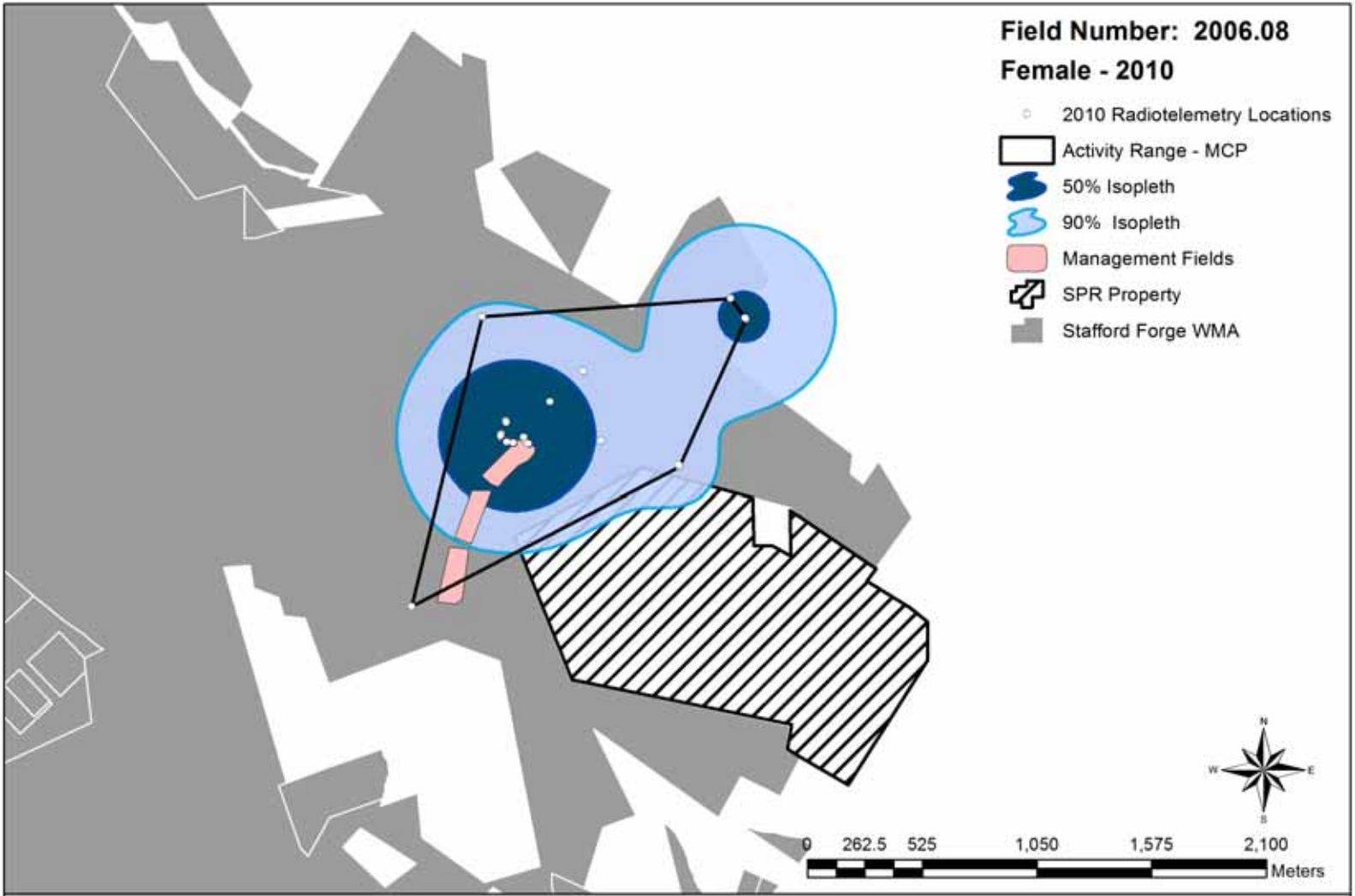
Based upon the pine snake relocation GPS coordinates collected by HA while radio-tracking, the Endangered and Nongame Species Program reviewed, approved and generated the activity range maps provided in this report. Each base map shows the land boundaries of the SPR property, the Department's Stafford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

---

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

Because of an early April warm spell, this snake had already egressed from NH 2 by the time HA's radio-tracking activities commenced on 04/15/10. The snake was relocated 53 times throughout the 2010 field season (**Figure 11**). This snake spent the beginning of the activity season using habitat in or near MF 3. On 04/23/10, the snake was found heading down a recently excavated mole tunnel, where it remained for four days. On 05/03/10, it was pulled from the field for transmitter re-implantation surgery. After its release, this snake once again used the enhanced habitat along the border of MF 3. Snake number 2006.08 spent approximately a month, from mid May to mid June, basking and concealed in and along the earthen berms of MF 3 until making a move towards the east/northeast. Over the next month and a half this snake made a series of foraging forays in the upland forest and continued to move east/northeast towards Route 72. It spent three days in early August foraging in the Mill Creek wetland corridor, before continuing to the adjacent upland pine/oak forest.

Eventually, the snake spent ten days, during the beginning of September, underground in a mammal burrow less than five meters from the edge of the parking lot of the Nursing and Rehabilitation Center on Route 72. Like many of our other study snakes, it is possible that the heat and lack of rain throughout the summer likely caused it to stay underground for long periods of time. The snake finally emerged from the burrow and made a large move of approximately 1.2 kilometers in a matter of two days through the Mill Creek wetland corridor and across Hay Road back to the vicinity of its hibernaculum (NH 2). The snake was observed basking less than a meter from the den on 09/29/10 and 10/07/10. On 10/20/10 the snake was found shedding under a scrub oak five meters from its den entrance. After shedding the snake was not seen above ground for the remainder of the season and is currently overwintering again in NH 2.



**Figure 11.** 2010 activity range of pine snake 2006.08, showing 100% minimum convex polygon (MCP), and 50% and 90% kernel density estimator isopleths (KDE).

|         | Acres  | Hectares |
|---------|--------|----------|
| MCP     | 291.40 | 117.92   |
| KDE 50% | 104.06 | 42.11    |
| KDE 90% | 449.78 | 182.02   |



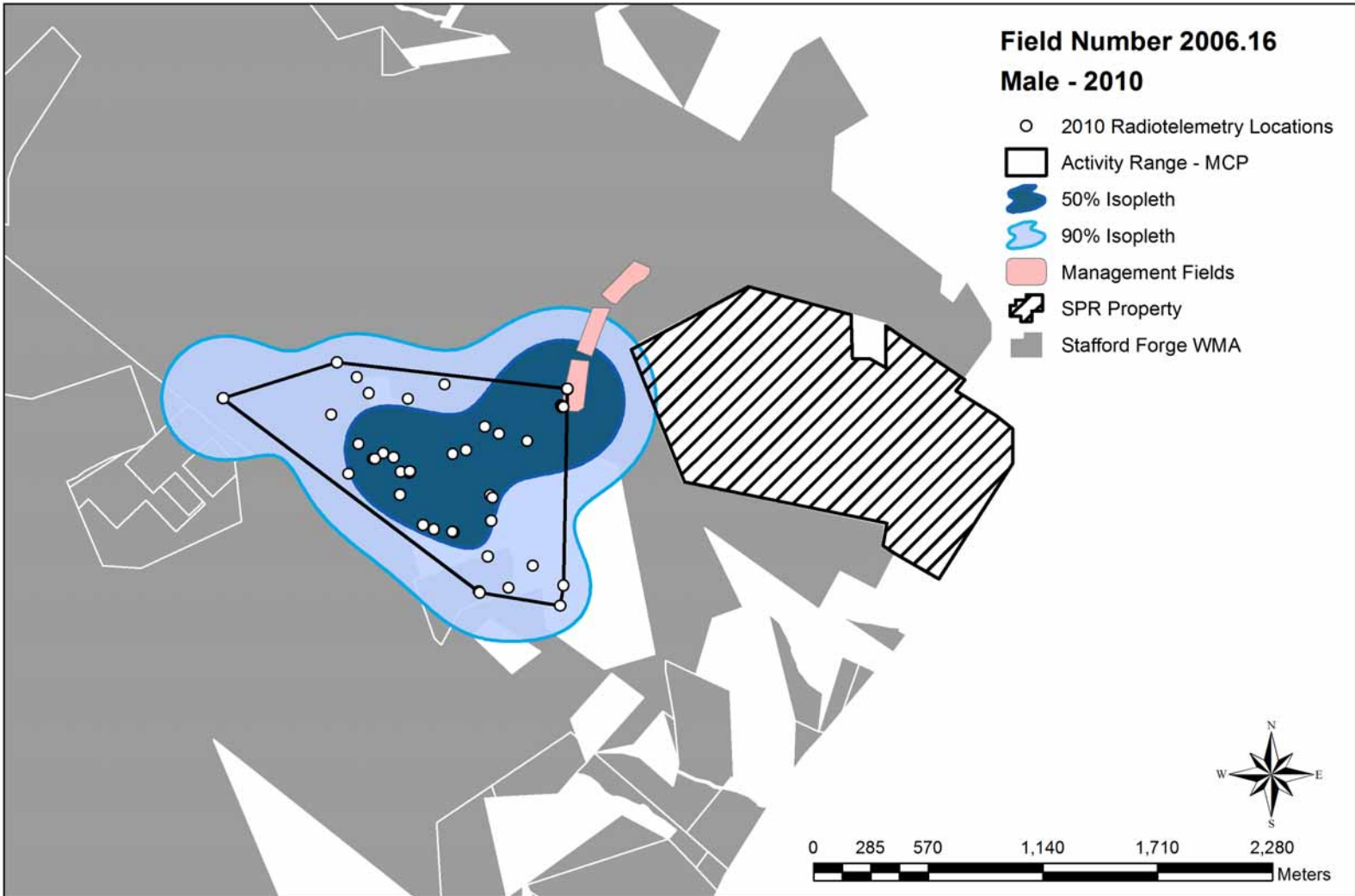
**N. Pine Snake No. 2006.16** (♂). (Shifted Snake, Treatment C/Lab) Current status = Alive and healthy. This snake was originally captured by EcolSciences, Inc. in trap number 27 along the perimeter drift fence on 05/18/06.

Unseasonably warm weather in April most likely caused this snake to egress from AH 1 prior to the commencement of radio-tracking activities on 04/15/10. It was relocated 66 times during the 2010 field season (**Figure 13**). On 04/17/10 it was pulled from the field for transmitter re-implantation surgery. Following surgery, the snake was released into the wild on 05/01/10. On the very next relocation (05/03/10) this snake was observed mating with female pine snake 2006.19 (**Figure 12**). It was observed restraining pine snake 2006.19 by the neck, however, actual copulation was not noted by HA staff due to inclement weather. Following the mating observation this snake made a large move into a pine/oak forest southwest of the management fields in an area known as the “Glass Pile” (see Appendix IV). In early May, the snake was relocated in close proximity to other snakes on two occasions, but no other mating activities were observed. In a manner consistent with prior field seasons, the snake used this area of forest for foraging purposes and would return to the earth berm in the southwest corner of MF 1 to shed.

In June, this snake selected the hollow cavities of fallen pine and oak trees for shelter, most likely seeking refuge from the heat. Although it was never observed feeding, this snake was often relocated in mole tunnels. On 06/25/10, the snake made a large move west, across Micaja Road and settled under a scrub oak to shed. After ten days, the snake returned to the area of pine/oak forest it had previously been using. On 07/23/10, the snake made another large move to the west and settled in a dirt mound in the southwest edge of MF 1. The hot and dry conditions may have caused the snake to remain underground at this location until 08/06/10. Throughout the rest of August and September, the snake remained in the area of the management fields, mostly remaining underground. By 10/07/10 this snake had returned to AH 1 where it has overwintered previously in 2007, 2008 and 2009 seasons.



**Figure 12.** Male Pine Snake 2006.16, was photographed aggressively mating with female Pine Snake 2006.19. Radio-tracking allows biologists to observe the secretive behavior of snakes. Photo by Bob Hamilton, HA Staff.



**Figure 13.** 2010 activity range of pine snake 2006.16, showing 100% minimum convex polygon (MCP), and 50% and 90% kernel density estimator isopleths (KDE).

|         | Acres  | Hectares |
|---------|--------|----------|
| MCP     | 302.28 | 122.33   |
| KDE 50% | 194.91 | 78.88    |
| KDE 90% | 607.52 | 245.85   |

**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.

Because of an early warm period in April, this snake had already egressed from AH 1 when radio-tracking activities commenced on 04/15/10. It was relocated 56 times during the 2010 activity season (**Figure 15**). This female snake was almost always relocated in or near the created wildlife management fields during the entire Summer season. The farthest this snake was ever relocated away from the management fields was approximately 350 meters west. During the 2010 field season this snake was observed in courtship on three separate occasions with three different males. On 04/29/10 this female snake was observed being courted by an unknown male pine snake. For approximately thirty minutes the male pine snake was observed tongue flicking this snake and crawling on top of her, however, this snake never seemed receptive to the male. Eventually the unknown male coiled up amongst some new growth pitch pine a meter from this snake's location with no copulation occurring. Then, on 05/03/10 this snake was observed being restrained by male pine snake 2006.16. However, as mentioned in the synopsis for pine snake 2006.16, actual copulation between the two was not observed due to inclement weather. Finally, on 05/15/10 this snake was observed mating with male Pine snake 2006.108 along the western berm of MF 2. Due to vegetation obscuring the researcher's view, only the restraining of this snake by the male was observed, not actual copulation. After approximately twenty minutes the male released the female and retreated towards the management field berm. Even though HA staff never observed actual copulation, only courtship, between this snake and the male snakes, she did become gravid.

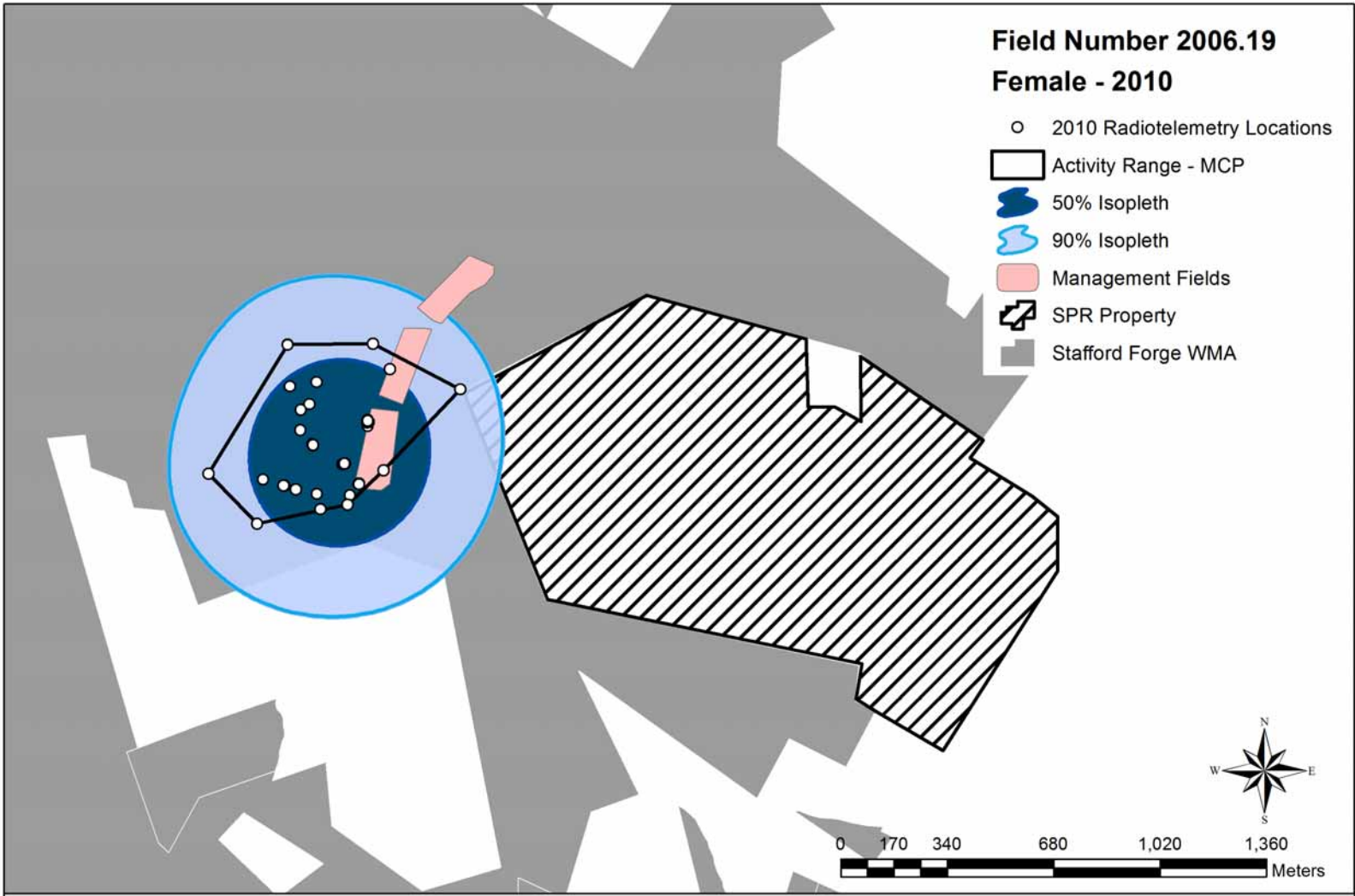
This snake nested in the western berm of MF 1 sometime between the dates of 06/12/10 and 06/17/10. Although, HA staff searched the immediate area of this snake's nesting location in the fall for hatchlings, none were observed, therefore, it is unknown if this snake's clutch successfully hatched. On 06/25/10, this snake was taken out of the field to replace her old transmitter. After surgery, she was released in the same spot in MF 1. For the remainder of the summer (August through September), the snake stayed very close to the created wildlife management fields. She spent the majority of the time underground in earth mounds or stump holes, but was observed



concealed in the leaf litter on 09/01/10 and 09/21/10. On 10/06/10, this female snake entered her man-made hibernacula (AH1), where she is currently overwintering.

**Figure 14.** Adult female number 2006.19 basking on pine needles. Photo by Bernd Skubowius.





**Figure 15.** 2010 activity range of pine snake 2006.19, showing 100% minimum convex polygon (MCP), and 50% and 90% kernel density estimator isopleths (KDE).

|         | Acres  | Hectares |
|---------|--------|----------|
| MCP     | 69.52  | 28.13    |
| KDE 50% | 66.75  | 27.01    |
| KDE 90% | 225.73 | 91.35    |



**Figure 16.** Red Fox are known to prey upon a variety of vertebrate animals, including rodents, birds, reptiles and amphibians. Pine Snakes are often killed and eaten by both Red Fox and Coyote. Photo by Bob Zappalorti, HA.

*N. Pine Snake No. 2006.26* (♂). (Shifted Snake, Treatment A/1 Winter) Current status = Undetermined/Lost. This snake was originally captured by EcoSciences, Inc. during the summer of 2006.

This snake had already egressed from its NH 14 when radio-tracking activities began on 04/15/10. It was relocated 13 times during the field season. For the remainder of April this snake utilized the berms and the forest adjacent to management fields 1 and 2. Then on 05/01/10 it made a large move to the south to the area known as the “glass pile” only to return to the vicinity of the management fields on the following location.

It spent another week along the berms of all three management fields until making a large move to the southeast towards the vicinity of Costco on 05/09/10. After this date 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. Because there were so few relocation points for this particular pine snake, an activity range map was not generated.



**Figure 17.** An assortment of native warm season grasses and some shrubs have finally established themselves on the Management Fields. This is a southeastern view of pine snake Management Field One. Photo by Bob Zappalorti, HA.

***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.

Unseasonably warm sunny weather most likely caused this snake to exit from NH 30 prior to the commencement of radio-tracking activities on 04/15/10. It was relocated only 12 times during the 2010 field season before it went missing. From mid April to mid May this snake was consistently relocated in or near the Cedar Run wetland corridor that bisects the southern portion of the study site.

Additionally, this snake was also relocated on a couple of occasions on or near the landmark known as the “Glass Pile.” During this time this snake looked as though she may have become gravid, even though she was never observed mating or in the vicinity of a male snake.

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

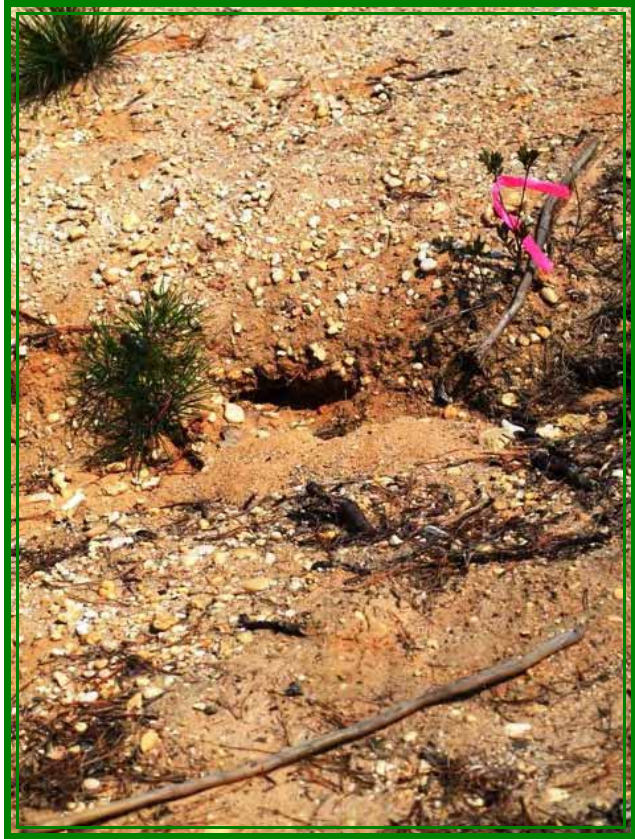
relocated pine snake number 2006.28’s radio-transmitter. It was found on a vegetated island in the middle of a wetland corridor. The antenna wire on the radio-transmitter was chewed or snapped off. There were no scales, bones, or remnants of the snake’s carcass and was probably eaten.

It is unknown why HA staff was unable to get a signal for this snake’s transmitter prior to July 13, even though HA repeatedly searched the exact same area of forest where the transmitter was found previously. The attack on pine snakes by coyote or red fox predators has been observed in the Pine Barrens by HA and is one possible explanation for the death of this snake (**Figure 16**). Because there were so few relocation points for this snake, an activity range map was not generated.



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

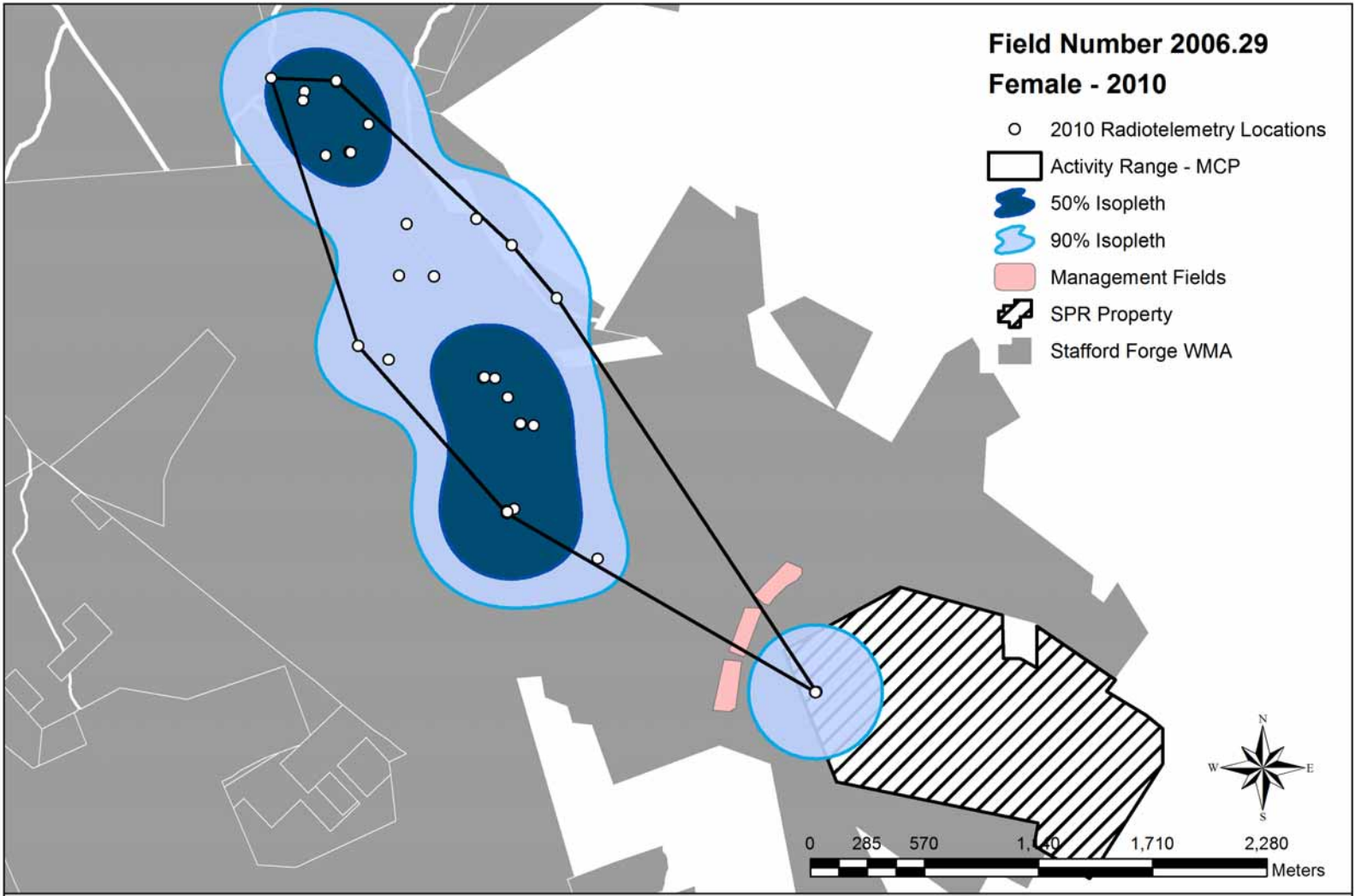
This snake had already egressed from NH 20 prior to the start of radio-tracking activities on 04/15/10. During the course of the season it was relocated 40 times (**Figure 19**). The snake was first located 434-meters from its overwintering site. On 04/17/10, the snake was pulled from the field for transmitter replacement and released at the same location after re-implantation. On 05/10/10 this snake was found mating with pine snake 2007.10, a male pine snake that it mated with last season. The snake spent the remainder of May shifting between the Mill Creek wetland corridor, and the adjacent upland pine forest. It then headed for the SPR property, presumably for nesting. On 06/15/10, the snake successfully breached the perimeter drift fence and was found beneath an old rusted metal barrel. On 06/17/10, Pine snake 2006.29 was relocated on the edge of the SPR property, very close to the Rutgers weather station tower.



**Figure 18.** The successful nest site chosen by female Pine Snake 2006.29. The sand dump pile and entrance are visible, even after it had rained. Photo by Bob Zappalorti, HA.

A distinct nest excavation and sand dump-pile was noted 3.6 meters from the snakes' relocation site. (This was not a nest site documented on the SPR property during the original 2006 nest surveys). The female made her nest on a slope, at the edge of a small rainwater gully (**Figure 18**). She laid 10 eggs. This snake had attempted to nest on the landfill in 2009 as well, but became trapped in a drainage corral, and was moved into the forest by HA staff to prevent death.

For the majority of the summer (July through September), 2006.29 spent the much of her time foraging in the Mill Creek wetland corridor and adjacent upland pine forest, just as she had done in previous years. On 09/17/10, the snake was found in the root system of a mountain laurel in which red squirrels were using as a feeding station. This snake spent the rest of September and early October traveling south towards its favored hibernaculum. The snake crossed Hay Road on 09/25/10 and continued through the selectively thinned section of forest to the south. On 10/08/10, the 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 snake was found to have moved approximately 200 meters southeast to a very large mammal burrow. Why the snake chose to abandon its old successful hibernaculum in favor of a new one is unknown. This new den was designated as NH 36.



**Figure 19.** 2010 activity range of pine snake 2006.29, showing 100% minimum convex polygon (MCP), and 50% and 90% kernel density estimator isopleths (KDE).

|         | Acres  | Hectares |
|---------|--------|----------|
| MCP     | 583.95 | 236.31   |
| KDE 50% | 265.10 | 107.28   |
| KDE 90% | 874.46 | 353.88   |



*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. The presence of white-wash and the condition of the antenna wire of the transmitter, which was grazed and curled up, suggests a bird-of-prey was the reason for its death.

This condition is similar to transmitter antennas found near other dead study snakes during this investigation that had been predated upon by raptors. The process of the raptor's beak tearing the flesh off the body of the snake causes the antenna wire to curl up; much in the same fashion as when one would take a pair of scissors and run the blade across a piece of decorative ribbon.

It is likely that when pine snake 2006.32 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. HA has lost several of its study snakes to predators over the past four-years, especially the original 2006 shifted pine snakes. Because there were no new relocation points for this snake, an activity range map was not generated.



**Figure 20.** A Red-tailed hawk perched on a branch of a River Birch Tree. These raptors sit-and-wait for a small animal to move across the forest floor below them. Once the hawk sees its target, it drops down and attacks with its sharp, deadly talons and kill its prey. Photo by Matt McCort, 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 85 of the perimeter drift fence by EcolSciences, Inc. on 08/31/06.

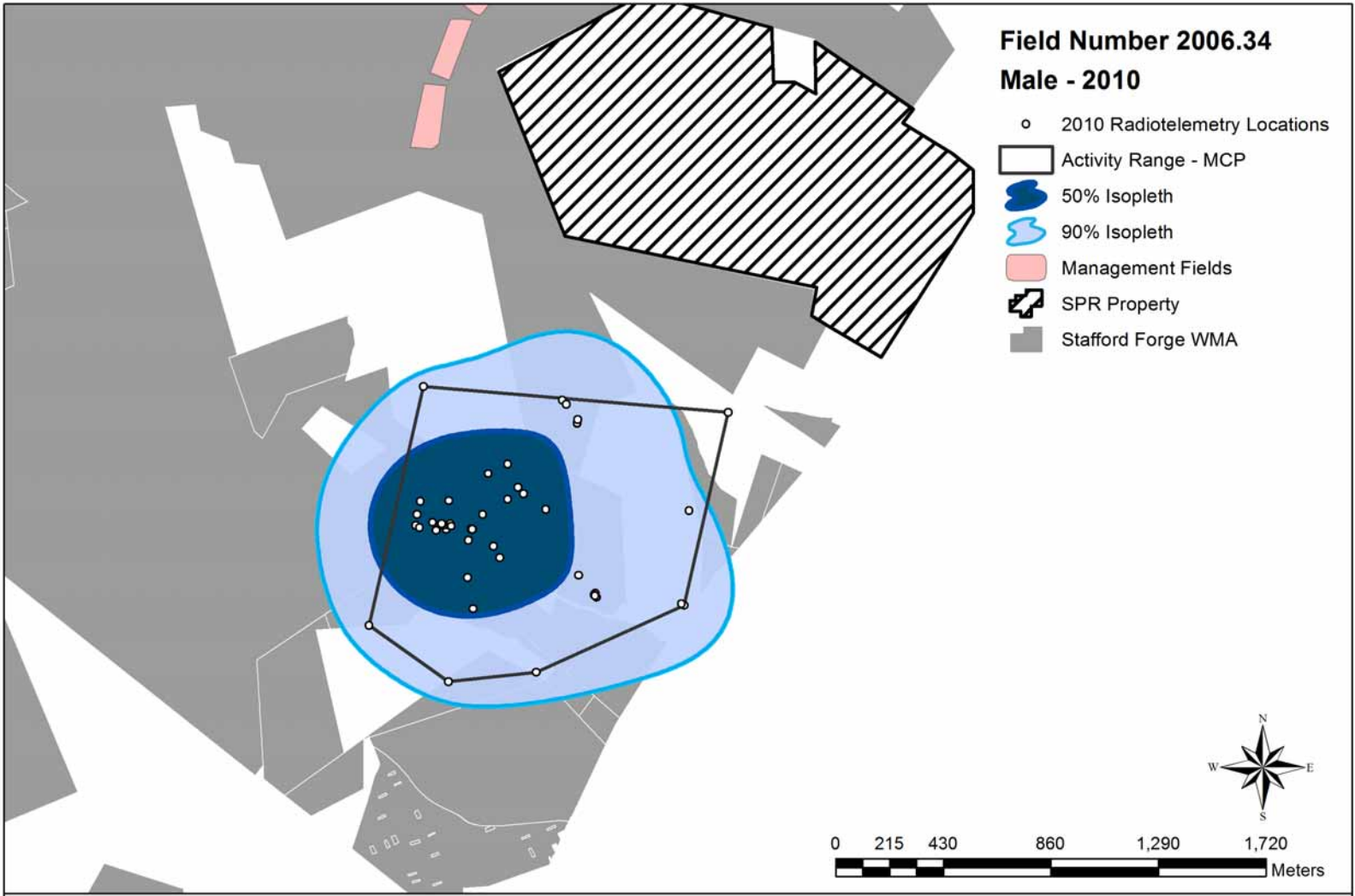
This snake had already egressed from NH 34 prior to the commencement of radio-tracking activities on 04/15/10. It was relocated 50 times during the 2010 field season (see **Figure 21**). At the beginning of the season this snake made a series of small to moderate sized moves in a section of oak/pine forest southeast of the management fields. This section of the Stafford Forge Wildlife Management Area forest has been used by this snake in past field seasons.

At the beginning of the 2010 field season, this snake was often relocated near female pine snake 2007.05, the same snake that was observed mating with 2006.34 during the three previous field seasons. However, during 2010 this snake was never observed mating with pine snake 2007.05. It was however, observed on two separate occasions mating with two other female snakes. On 04/29/10 this snake was found on top of an unknown female pine snake. Unfortunately, both snakes slipped down a nearby mammal burrow before the researcher was able to confirm that copulation was occurring. Then on 05/07/10, this snake was observed mating with female pine snake 2008.13. This time, HA staff observed copulation between the two snakes.

For the remainder of the field season this snake continued to use a large area of oak/pine forest, forested wetland, and pine forest habitat southeast of the management fields. On 05/30/10, it was relocated approximately 6 meters up in a pitch pine tree, but HA staff could not identify any prey items that the snake may have been searching for that high in the tree. Similar to the previous field season this snake was often found on or near the landmark known as the “Glass Pile.” It used an old shingle pile near the “Glass Pile” as a shedding station on at least one occasion during the season. It had been relocated using this same shingle pile as a shedding station in prior field seasons as well. It was also observed using an old abandoned motorcycle gas tank for shelter. It’s interesting to note that not only did snake 2006.34 use this old gas tank, but other study snakes have been observed using it in the past as well. This snake was also found inside mole tunnels on several occasions indicating possible foraging activity, but was never observed feeding on a prey item.

On 08/02/10, this snake was removed from the field for transmitter replacement. On 08/20/10 it was returned to the field and spent the remainder of August and beginning of September in the vicinity of the “glass pile.” Then, in mid-September this snake made a moderate sized move to the north into a small elevated section of oak/pine forest. The next time it was relocated it went back to the “glass pile.” Subsequently, it again returned to the same elevated section of forest where it eventually overwintered in a stump hole. This is a newly identified den and is designated NH 37. In comparison to previous field seasons, the home range for this snake in 2010 was rather small. It did not travel nearly as far north or south as it has in past field seasons.





**Figure 21.** 2010 activity range of pine snake 2006.34, showing 100% minimum convex polygon (MCP), and 50% and 90% kernel density estimator isopleths (KDE).

|         | Acres  | Hectares |
|---------|--------|----------|
| MCP     | 311.67 | 126.13   |
| KDE 50% | 120.47 | 48.75    |
| KDE 90% | 469.43 | 189.97   |

***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.

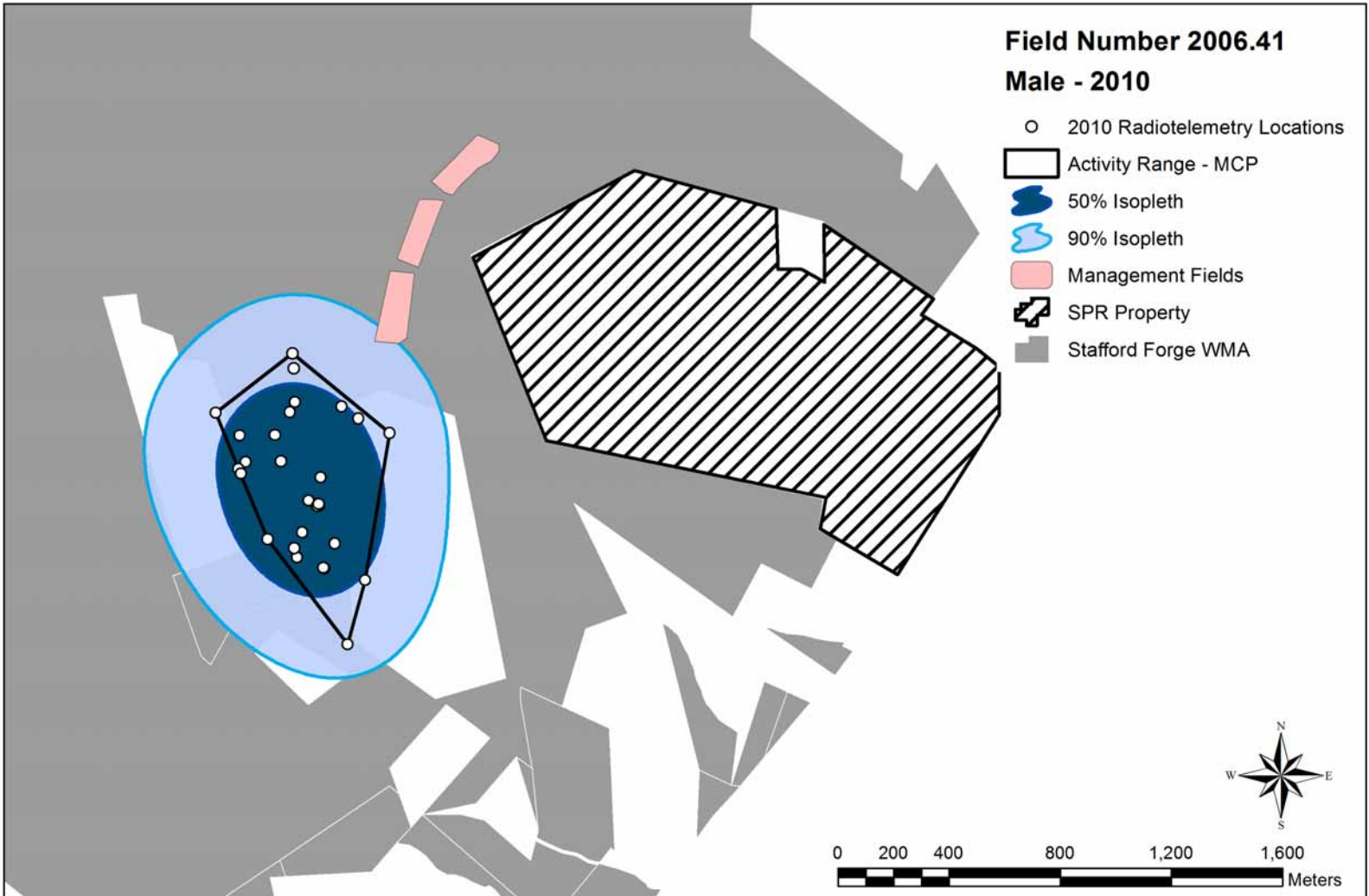
This snake was recaptured by HA staff in late May as it crawled across a dirt road (known as Slocum Road) approximately 800 meters southwest of the management fields. This snake was from a 2006 clutch of eggs that was hatched out in HA's laboratory and was released into AH 1 in the fall of 2006. It had been recaptured by HA staff in both 2008 and 2009 at AH 1, however, it did not have adequate body size to be implanted with a transmitter at those times.

However, when it was recaptured in the 2010 season it was considered large enough to be implanted with a one year transmitter. Following radio-transmitter implantation surgery, pine snake number 2006.41 was released on 06/10/10, at its original capture location off Slocum Road. This young male pine snake was relocated 32 times in 2010 (**Figure 22**).

This snake was regularly relocated in an area of oak/pine forest south/southwest of the management fields near Slocum Road and the landmark known as the "turtle pond." When this snake was in shed it was often relocated inside an old fallen pitch pine just off of Slocum Road for several days at a time. This strongly suggests that the snake was using the pine log as a shedding station.

On 07/25/10 this snake was relocated with the majority of its body inside a mole tunnel behaving as if it was attempting to subdue a prey item. After approximately ten minutes the snake emerged from the tunnel with an eastern mole in its mouth. This pine snake was a relatively small snake and the eastern mole looked a little large for the snake to consume. However, it had no problem eating the mole. After finishing the mole it continued to move about the general area in a slow deliberate manner, as if trying to locate another prey item.

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.



**Figure 22.** 2010 activity range of pine snake 2006.41, showing 100% minimum convex polygon (MCP), and 50% and 90% kernel density estimator isopleths (KDE).

|         | Acres  | Hectares |
|---------|--------|----------|
| MCP     | 88.48  | 35.81    |
| KDE 50% | 87.93  | 35.58    |
| KDE 90% | 289.48 | 117.15   |



**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.

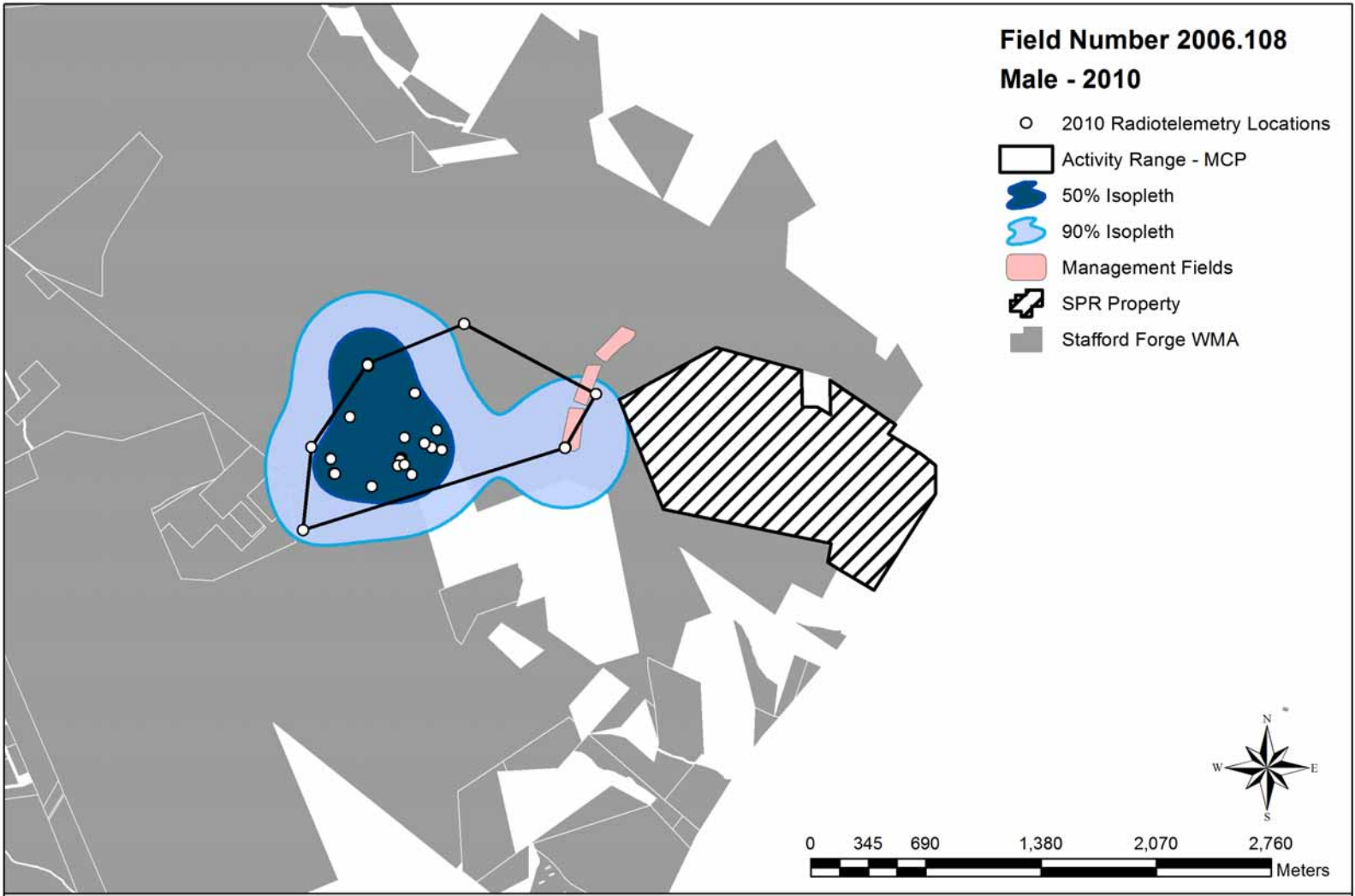
This adult male pine snake 2006.108, was relocated 51 times during the course of the 2010 field season (see **Figure 23**). It was originally recaptured on 05/15/10, when it was found mating with female pine snake 2006.19, behind the western earth berm along MF 2. HA staff did not collect the snake until copulation had been completed. It was then captured while retreating towards the shelter of the berm. This snake was implanted with a transmitter on 06/01/10, and subsequently released back into the wild.

Following its release, this snake made a large move of just over a kilometer and a half to the southwest and was relocated in a root cavity along the western edge of Micaja Road. It would be relocated in this same root cavity several times throughout the course of the field season. In fact this snake seemed to utilize certain areas on a fairly regular basis especially in conjunction with its shedding cycle. One such “shedding station” was a large debris pile comprised of tin and sand that was located along the edge of Micaja Road near the landmark known as the “Beach Pond.” A former study snake (pine snake 2006.33, which is now deceased) was observed in this same debris pile in prior field seasons. This snake also used a stump hole (while it was in shed) located in the upland oak/pine forest east of the intersection of Micaja and Slocum Roads. This is the same area of forest that pine snake 2006.16 was often relocated in during the field season.

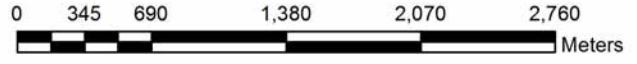
For the majority of the field season this snake was often relocated in the section of oak/pine forest mentioned above or in pine forest habitat west/southwest of the management fields. Then, on 08/21/10 the snake made a fairly large move back to the management fields. This snake spent the next two weeks concealed in the berm along the south edge of MF 1. There were two other study snakes (pine snakes 2006.16 and 2006.19) that were concealed within 6 meters of this snake in the same berm. On 09/13/10 the snake was located within 20 meters of the perimeter drift fence that surrounds the SPR site east of MF 2. After that observation, it made a very large move of approximately 1 kilometer into upland pine forest west of the management fields and was relocated in a large mammal burrow. This burrow was discovered to be a new hibernaculum this season (Pine snake 2006.29 is overwintering in this burrow). However, this snake left this location and was relocated in NH 5 on 09/29/10. This den has also been used by pine snake 2008.03 and Pine snake 2006.33 (before becoming deceased) during prior winter seasons. This snake was never again seen above ground from 09/29/10 to the end of the field season. Pine snake 2008.03, is again overwintering at this location.

**Field Number 2006.108  
Male - 2010**

- 2010 Radiotelemetry Locations
- Activity Range - MCP
- 50% Isopleth
- 90% Isopleth
- Management Fields
- SPR Property
- Stafford Forge WMA



**Figure 23.** 2010 activity range of pine snake 2006.108, showing 100% minimum convex polygon (MCP), and 50% and 90% kernel density estimator isopleths (KDE).



|         | Acres  | Hectares |
|---------|--------|----------|
| MCP     | 299.60 | 121.24   |
| KDE 50% | 153.44 | 62.09    |
| KDE 90% | 517.69 | 209.50   |

**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.

This snake had already egressed from NH 14 by the time radio-tracking activities commenced on 04/15/10. This snake was relocated 26 times during the 2010 field season (see **Figure 25**). On the very first relocation, it was found in very close proximity to male pine snake 2006.34. These two snakes had been observed mating during the 2008 and 2009 field seasons. This female was also originally captured in 2007 when she was found emerging from a stump hole next to pine snake 2006.34. However, this female snake was never observed mating with any male snakes during the 2010 season. During all prior field seasons this snake became gravid, but this was not the case in 2010, as HA never observed mating and/or nesting by this snake.

For the majority of April this snake made a series of small moves to the north traveling through pine/oak forest that borders the Garden State Parkway. On 04/22/10 this snake was seen following a scent trail, using rapid tongue flicking. It attacked and constricted some cottontail rabbit pups and then systematically devoured the entire litter (**Figure 24**). On 04/29/10 this snake was found basking in a section of forest that contains a den it had used in the past. During this relocation a coyote trotted within 20 meters of the snake and the HA researcher. The snake stayed in this area of forest for approximately the next week and a half while going through a shedding cycle. Between 05/12/10 and 06/03/10, this snake made a series of small to moderate sized moves within its home range that had been established during prior seasons. On 06/04/10, it returned to the same location it had used in the early part of May during a shedding cycle.

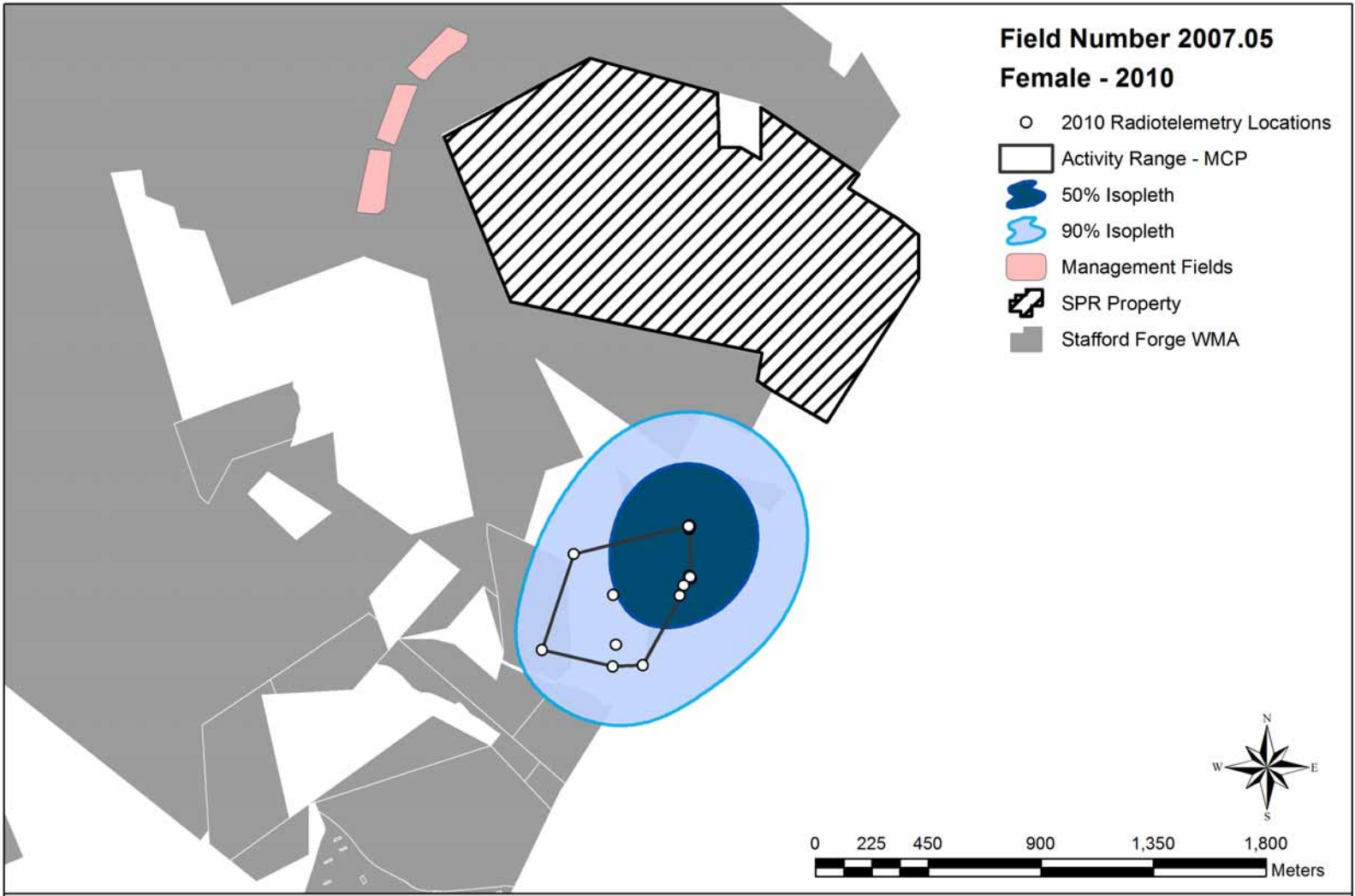
It was relocated in this same spot until 06/19/10, after which HA staff was unable to pick up a signal from the snake's transmitter. Despite repeated efforts throughout the remainder of the field season HA staff was not able to relocate this snake. It is unknown what has happened to cause the transmitter 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.



**Figure 24.** With fur still in its mouth, female Pine Snake 2007.05 emerges from an Eastern Cottontail Rabbit's nest after eating four pups. Photo by Bob Hamilton, HA Staff.

As mentioned previously, one snake was found predated upon and another went missing in this same section of the forest at the beginning of the field season. It's possible that coyote or red fox are preying upon HA's study snakes in this area of the forest.





**Field Number 2007.05  
Female - 2010**

- 2010 Radiotelemetry Locations
- Activity Range - MCP
- 50% Isopleth
- 90% Isopleth
- Management Fields
- ▨ SPR Property
- Stafford Forge WMA

**Figure 25.** 2010 activity range of pine snake 2007.05, showing 100% minimum convex polygon (MCP), and 50% and 90% kernel density estimator isopleths (KDE).

|         | Acres  | Hectares |
|---------|--------|----------|
| MCP     | 55.77  | 22.57    |
| KDE 50% | 74.80  | 30.27    |
| KDE 90% | 266.18 | 107.72   |

**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 pine snake had already egressed from NH 33 prior to the start of the radio-tracking field season on 04/15/10, and had moved into the forest within its home range. During the course of the 2010 field season it was relocated 59 times (**Figure 27**). This snake spent the beginning of the spring in an upland oak/pine forest towards the eastern edge of the Stafford Forge WMA. On 04/21/10, the snake was found excavating a mole burrow at the base of a small scrub oak (*Quercus ilicifolia*). It remained underground for several days, before moving approximately 50 meters east of the Mill Creek wetland corridor. On 05/06/10, the snake was found engaged in courtship behavior with another of HA's study snakes, pine snake 2007.10 in the ecotone between the wetland and upland pine/oak forest. In the past, these two study snakes often frequented the same area of forest in the vicinity of an old power cut (see **Appendix IV**). On 05/14/10, it was found mating with a different male pine snake, which was new to the investigation. (now known as Pine snake 2010.03).

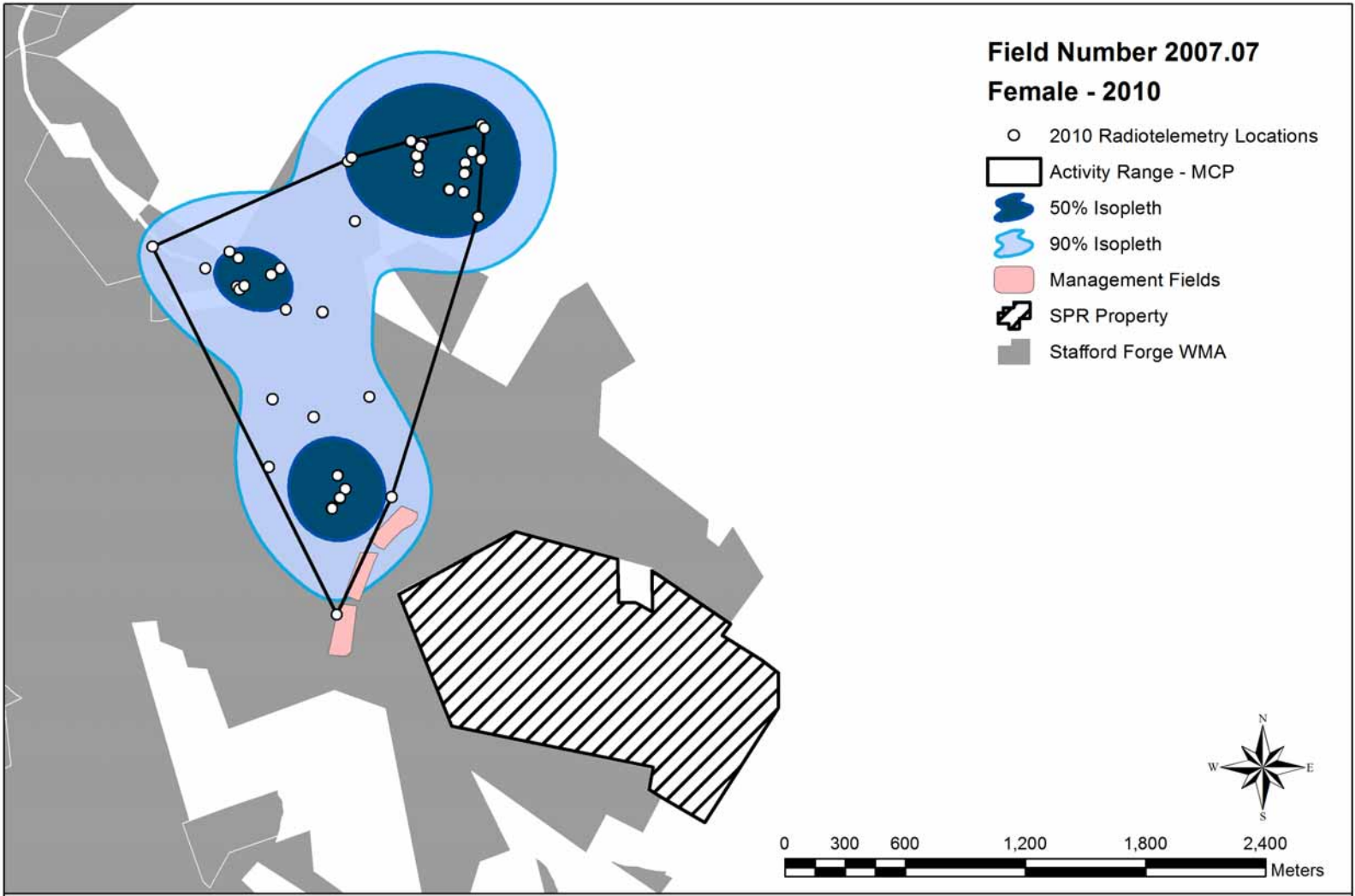
In early June, the snake moved east, across the Mill Creek wetland and Hay Road, and settled in the berm along the western edge of MF 1 to lay her eggs. Interestingly, this snake used an existing chamber also used by 2006.19. After laying her eggs the snake then moved in a northeasterly direction, and spent much of July in a mound of cut trees and branches made by the NJ Division of Parks and Forestry along Hay Road. It subsequently continued to travel northeast and crossed the Mill Creek wetland into upland pine/oak habitat to forage where it remained for several days. During the summer (late July to early August), this snake spent three weeks in very close proximity to Route 72, getting as close as 25 meters from the edge of the highway. It then moved south and was relocated several times between 09/08/10 and 09/18/10 underground in a mammal burrow on a hillside within 20 meters of a gully along Mill Creek.

The snake subsequently emerged freshly shed and was observed foraging at its next three relocations. From 09/24/10 to 10/07/10, the snake was concealed in the root system of a large mountain laurel (*Kalmia latifolia*) bush. On 10/10/10, the snake entered a hibernaculum it had used in the past. However, on 10/13/10 the snake had left the natural den and made a large movement to the west. It once again crossed the Mill Creek wetland and Hay Road, and was found in the vicinity of the management fields.

Over the next few weeks, the snake was relocated traveling along the same tract of forest between the fields and the Hay Road pond, in the vicinity of the den it utilized in the first two field seasons. On 10/28/10, the snake finally settled under the base of a half fallen pine tree where it appears to be hibernating for the winter. This is a newly discovered natural den and was designated as NH 38.



**Figure 26.** Female Pine Snake 2007.07 hissing.



**Figure 27.** 2010 activity range of pine snake 2007.07, showing 100% minimum convex polygon (MCP), and 50% and 90% kernel density estimator isopleths (KDE).

|         | Acres  | Hectares |
|---------|--------|----------|
| MCP     | 511.66 | 207.06   |
| KDE 50% | 196.73 | 79.61    |
| KDE 90% | 705.02 | 285.31   |



*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 concealed within a trash pile.

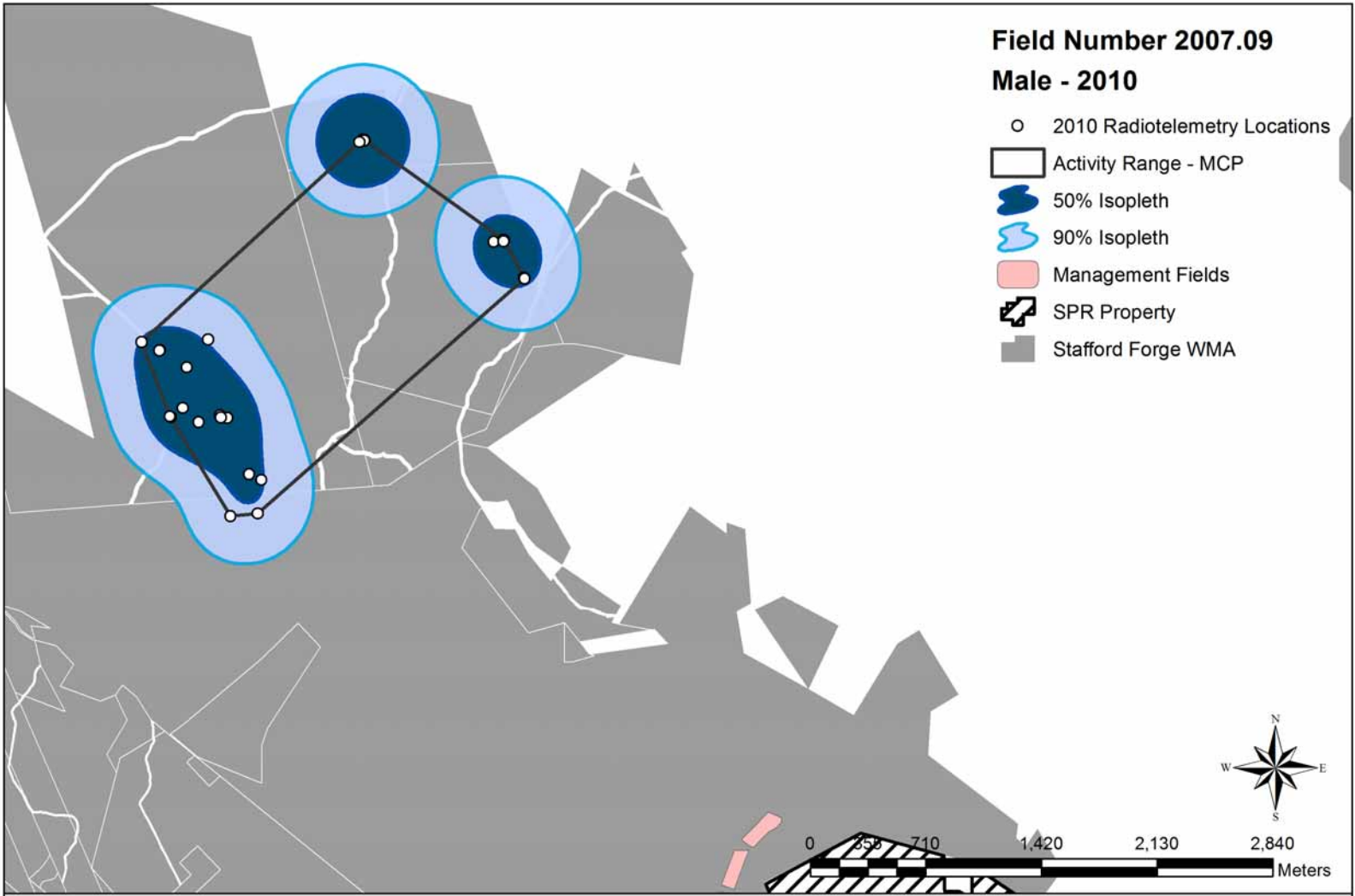
Because of an unusually warm Spring, this snake had already egressed from NH 25 prior to the start of radio-tracking activities on 04/15/10. This specimen was relocated 31 times throughout the activity season (**Figure 29**). As in previous years, this snake spent late April in close proximity to its hibernaculum, moving from one stump hole to another. Also, following its previously observed habits, the snake then made a large move west to an open-canopied oak/pine forest along Micaja Road. The snake was relocated very close to an old burnt out tire it had used for shedding on two occasions previously. On 05/11/10, the snake was found to be opaque and resting in a debris pile approximately 70 meters east of Hay Road, where it remained until 05/25/10. HA staff did not observe any interaction with any other snake during the mating season. The snake was relocated in the same tract of forest along Micaja Road from June to early August.

Sometime in early August, male 2007.09 made an extensive move somewhere into the Stafford Forge WMA forest. On 08/19/10, despite repeated attempts for several weeks, the snake could not be relocated. HA suspected that this snake made a very large move out of its normal home range or was killed by a predator.

After continued efforts by HA staff, the snake was finally relocated on 10/07/10, alive and healthy, when it returned to the area of pine/oak forest on private property where it hibernated in previous years. On 10/18/10, the snake was relocated approximately 2,500 meters from the northeastern border of Stafford Forge WMA. The snake was in a tract of upland pine habitat approximately 200 meters from a wetland on private property behind the Brighton at Barnegat housing development. This habitat is an open canopied, sparsely vegetated pine forest that could be potential nesting habitat. On 10/28/10, a new snake (pine snake 2010.06) was found basking outside of a burrow (now known as NH 39) where both snakes are currently overwintering.



**Figure 28.** Radio-tracked adult male Pine Snake number 2007.09, as it was found basking on oak leaves on the forest floor. Photo by Bob Hamilton, HA Staff.



**Field Number 2007.09  
Male - 2010**

- 2010 Radiotelemetry Locations
- Activity Range - MCP
- 50% Isopleth
- 90% Isopleth
- Management Fields
- ▨ SPR Property
- Stafford Forge WMA

**Figure 29.** 2010 activity range of pine snake 2007.09, showing 100% minimum convex polygon (MCP), and 50% and 90% kernel density estimator isopleths (KDE).

|         | Acres  | Hectares |
|---------|--------|----------|
| MCP     | 684.12 | 276.85   |
| KDE 50% | 226.49 | 91.66    |
| KDE 90% | 719.27 | 291.08   |

**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.

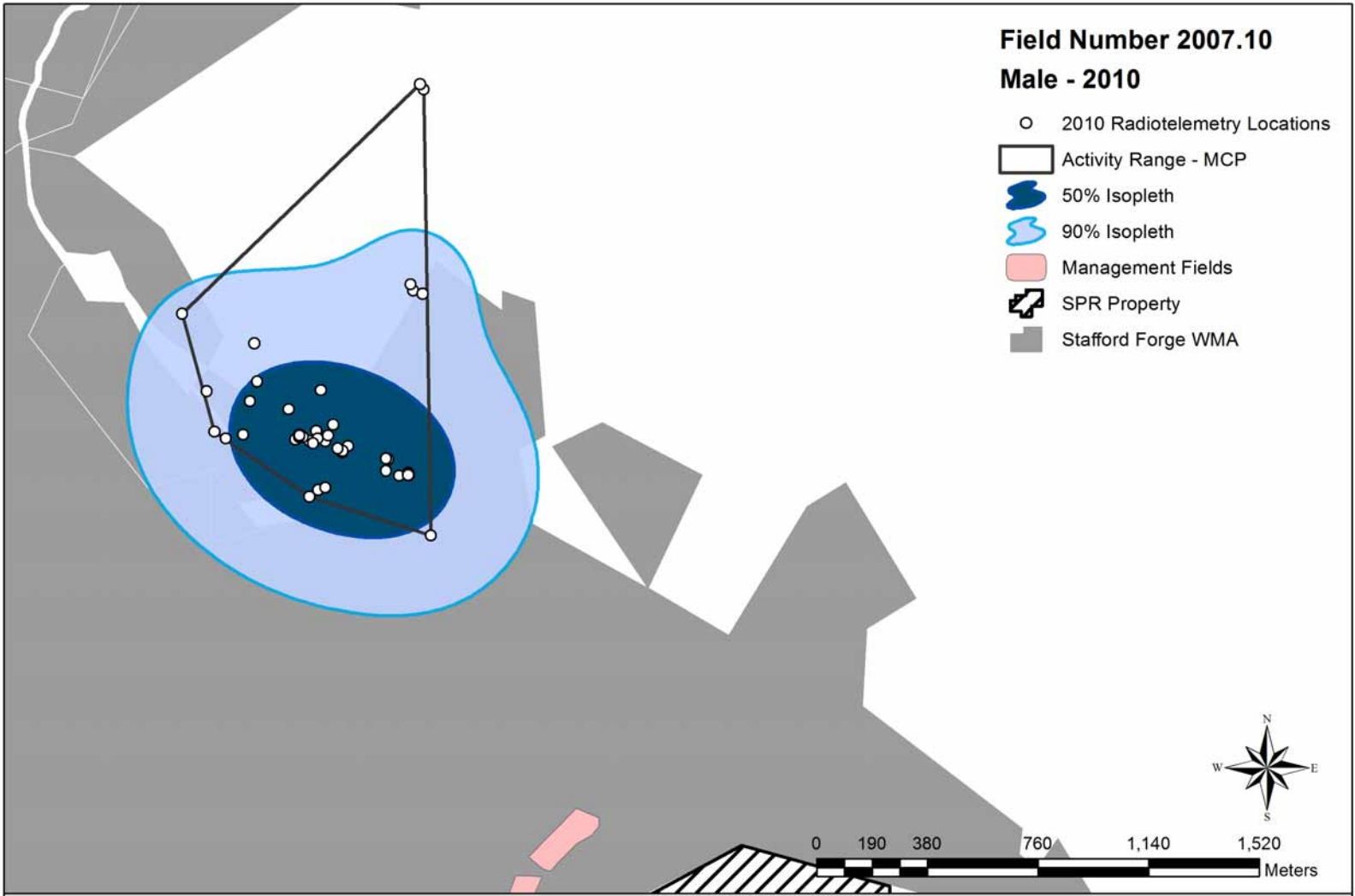
This snake had already egressed from NH 35 prior to the start of radio-tracking activities on 04/15/10. This snake was relocated 59 times throughout the season (see **Figure 31**). It spent the rest of April in the upland oak/pine forest near an old power cut where it had used the same area in previous seasons. On 04/23/10 and 04/28/10, the snake was found concealed in a hollow log elevated 60 cm from the forest floor, a refuge the snake had used several times in the previous year. The snake then moved south across the Mill Creek wetland corridor, and was observed mating with pine snake 2007.07 on 05/06/10. On 05/10/10, this snake was then found mating with pine snake 2006.29, the same female it had mated with the year before. It then returned north, to its favored oak/pine habitat near its hibernaculum for the remainder of May. Throughout June this snake was found foraging, basking, and underground in stump holes in the same patch of forest it has used during all prior field seasons. Throughout July and August this snake was consistently relocated in stump holes or hollow logs possibly due to the hot and dry weather conditions. However, on 08/19/10 it was found under an old discarded piece of plywood. On 09/06/10, the snake was found underground in a red squirrel (*Tamiasciurus hudsonicus*) feeding station. The snake then moved to a different mammal burrow approximately 150 meters to the north, where it remained from 09/11/10 to 09/20/10.

On 09/22/10, the snake was relocated approximately 5 meters off the ground in a hole in the side of a hollow tree on the edge of the Mill Creek wetland. Upon further investigation, HA staff noticed five juvenile red squirrels clinging to other trees within a few feet of the snake. Coils of the snake's body were seen moving within the hole, suggesting the snake had captured one of the squirrels and was in the process of constricting, killing and consuming it. On 09/26/10, the snake was relocated in NH 26 where it had overwintered in 2008. On 09/29/10, the snake had moved to a different known winter hibernaculum, NH 31, which was used by pine snake number 2009.13 the previous year. It was not observed basking above ground at any point after its arrival at the den on September 29, 2010.



**Figure 30.** Female Pine Snake 2006.29 is being courted by male Pine Snake 2007.10. Late April and May is when most adult male Pine Snakes seek receptive females. Photo by Bob Hamilton, HA Staff.





**Figure 31.** 2010 activity range of pine snake 2007.10, showing 100% minimum convex polygon (MCP), and 50% and 90% kernel density estimator isopleths (KDE).

|         | Acres  | Hectares |
|---------|--------|----------|
| MCP     | 201.57 | 81.57    |
| KDE 50% | 87.56  | 35.43    |
| KDE 90% | 348.50 | 141.03   |



**Figure 32.** Male Pine Snake 2007.11, was seen foraging along the edge of a dense wetland. The snake is shown here stretched-out and partially in the water, drinking. Photo by Bob Hamilton, HA Staff.

*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.

Due to an unusually early, warm Spring, this snake egressed from its winter den location before radio-tracking commenced on 04/15/10. It was relocated 70 times during the 2010 field seasons (**Figure 33**). 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.” This snake often used this habitat for shedding, foraging and overwintering.

On 04/17/10 this snake was observed with half of its body submerged in the landmark known as the “Spotted Turtle Pond.” While HA staff was collecting climatic data, the snake swam further into the middle of the pond. On 04/21/10, this snake was found courting and attempting to mate with female pine snake 2007.27. However, copulation was not observed between the two snakes. During the observation, the female pulled away from 2007.11 and crawled off. Due to inclement weather, HA staff had to return to their vehicle.

During May, this snake was relocated in and along the edge of the Cedar Run wetland corridor several times, possibly searching for potential prey items, although it was never relocated in the actual process of capturing or consuming a prey item (see the “Prey Availability for Pine Snakes” section below in the Discussion section).

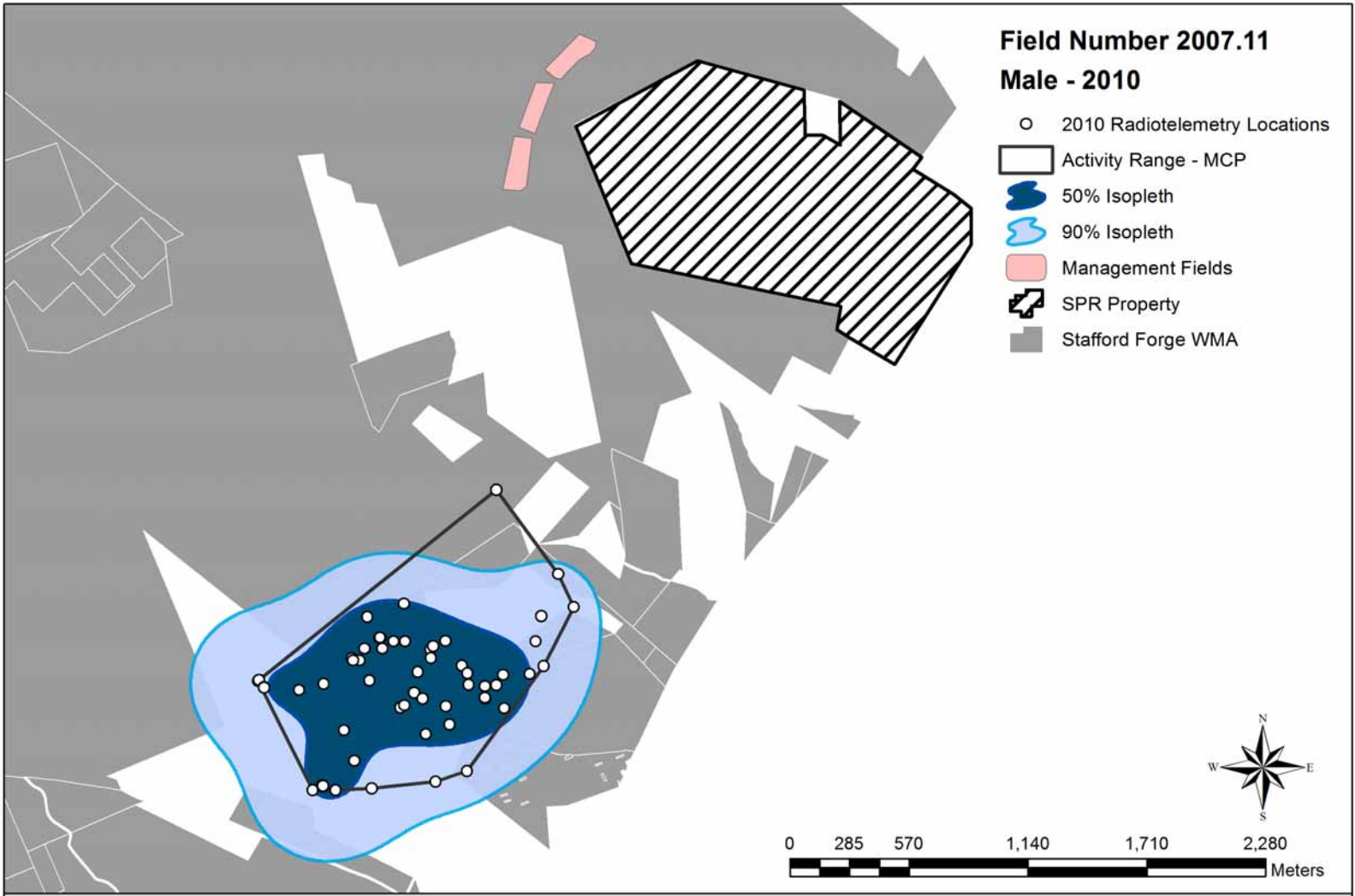
On several occasions during the 2010 season, this snake was found at or near areas it had used in prior years. However, there was only one period of time when this snake used an area of habitat that it had never been located within in previous years. This was in the beginning of August when it made a move into the far southeastern edge of the “Stafford Triangle.” For the next two weeks this snake was relocated in a moderate sized mammal burrow that was excavated into the side of an earth mound.

On 08/21/10, this snake was relocated in a section of upland pine forest northeast of the earth mound. It was an area of forest that had been heavily burnt in the 2007 fire and, as a result, there was very little overhead canopy structure intact. Nevertheless, there was a large amount of new low growth pitch pine that provided shelter along the forest floor.

This snake provided an interesting feeding observation when it was relocated coiled (constricting), around a freshly killed whip-poor-will (bird), that had been sheltering under some of the new growth pitch pine. The snake proceeded to consume the whip-poor-will in front of the observer. It then proceeded to head back to the “Stafford Triangle” and spent the last week of August and the first two weeks of September concealed under a tin pile that was covered with pine needles next to a large pine tree.

It then spent the remainder of September through the middle of October in an extremely large coyote burrow, not too far from the “tin pile.” Another study snake (pine snake 2007.14), was also concealed for a period of time inside the same mammal burrow towards the end of August and the beginning of September. By the end of October, this snake had returned to NH 8 where it has overwintered during the past three field seasons, thus demonstrating a strong fidelity to this den.





**Figure 33.** 2010 activity range of pine snake 2007.11, showing 100% minimum convex polygon (MCP), and 50% and 90% kernel density estimator isopleths (KDE).

|         | Acres  | Hectares |
|---------|--------|----------|
| MCP     | 307.22 | 124.33   |
| KDE 50% | 174.42 | 70.59    |
| KDE 90% | 513.68 | 207.88   |

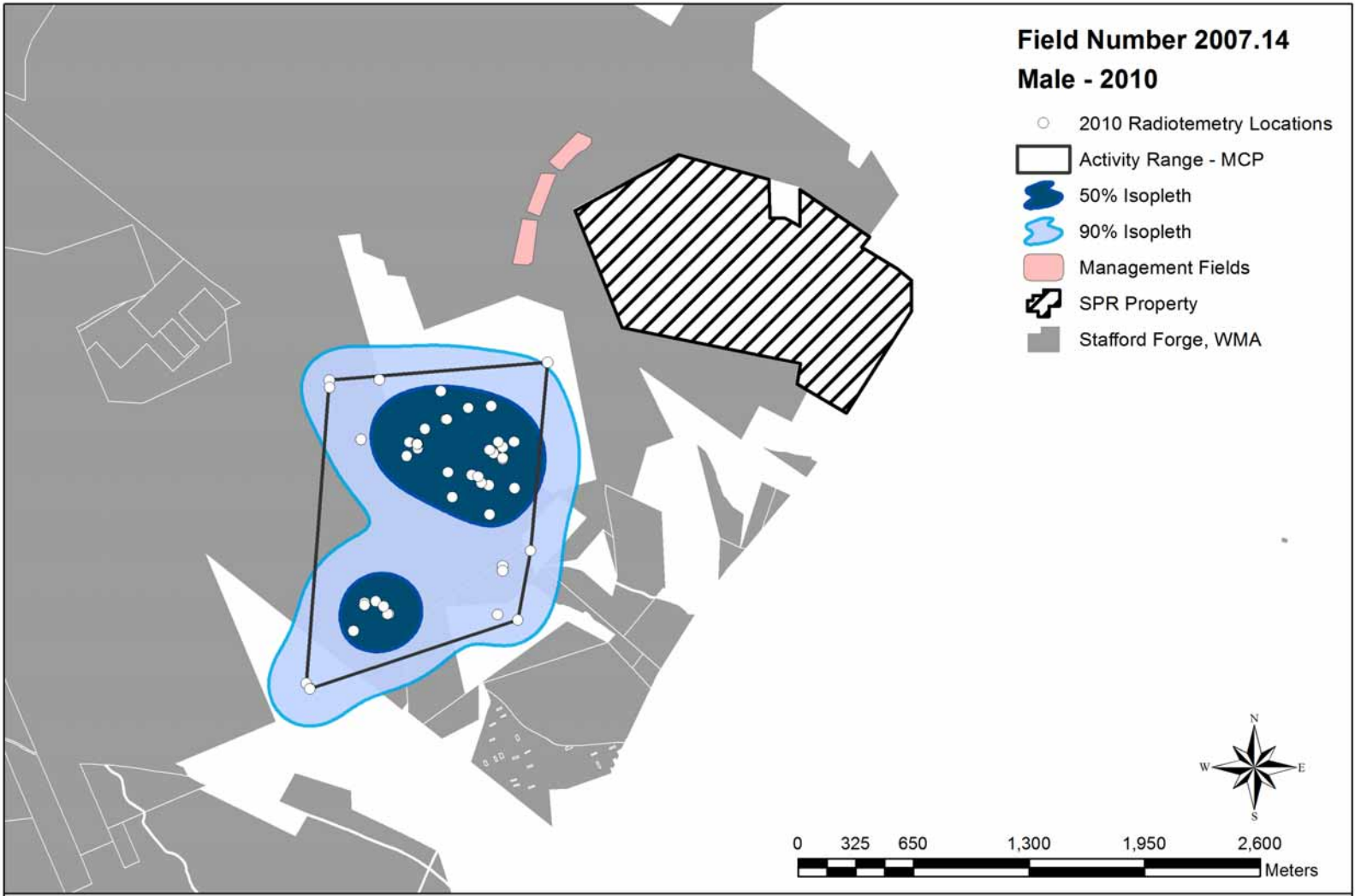
**N. Pine Snake 2007.14** (♂). Current status = Alive and healthy. This snake was originally captured on 08/11/07 near the landmark known as the glass pile, located south of the SPR property.

This snake had already egressed from its overwintering location by the time radio-tracking activities had commenced on 04/15/10. This snake was relocated 62 times during the 2010 field season (**Figure 34**). For the first half of the field season this snake was observed in much of the same habitat as it was in prior field seasons. This habitat includes upland pine forest, oak/pine forest, and forested wetland habitat south/southwest of the management fields. Much of this habitat borders the dirt roads known as Micaja Road and Slocum Road.

This snake was located on two separate occasions raiding eastern cottontail rabbit nests. The first occasion was on 05/15/10 when it was found raiding a nest in upland forest west of Micaja Road. When the observer located the snake it was in the process of constricting a baby rabbit. The observer noted that the nest was well concealed under some new growth pitch pine. Constriction of the baby rabbit continued for another five minutes before the snake began to consume the meal. The second observation occurred on 06/07/10 when the snake was found raiding a nest that was concealed by a large amount of leaf litter and new growth black oak. Because the nest was so well concealed the observer had difficulty viewing the snake or the young rabbits. However, a young rabbit was heard crying as the snake was thrashing about under the leaf litter. Eventually the snake emerged from the leaf litter with a young rabbit in its mouth. The snake began to consume the rabbit even though it was not dead yet. The rabbit continued to squeal and cry for the first five minutes while it was being eaten.

For the fourth year in a row this snake was relocated to the same location in a portion of the Cedar Run wetland corridor, while in a shedding cycle. On 08/04/10, this snake moved into a portion of pine/oak forest that it had never been observed using during past field seasons, however another study snake (pine snake 2006.28, which is now deceased), did also use this section of forest previously. For almost the entire month of August, this snake moved between two moderate sized mammal burrows in this area of forest. The snake was opaque (preparing to shed) for the majority of this time period.

During the last week of August the snake made a series of small moves west towards the area known as the “Stafford Triangle.” The snake spent a fair portion of September concealed in the same large coyote burrow that Pine snake 2007.11 was concealed in, or in the earth berms nearby. By 10/13/10 this snake had moved into NH 8. This particular snake had never used this hibernaculum to overwinter in before. However pine snake 2007.11, has overwintered in this den during every winter of the study. HA staff has observed and recorded other pine snakes, along with northern black racers using this winter den during this study.



**Figure 34.** 2010 activity range of pine snake 2007.14, showing 100% minimum convex polygon (MCP), and 50% and 90% kernel density estimator isopleths (KDE).

|         | Acres  | Hectares |
|---------|--------|----------|
| MCP     | 473.34 | 191.55   |
| KDE 50% | 182.45 | 73.83    |
| KDE 90% | 638.18 | 258.26   |



**N. Pine Snake No. 2008.02** (♂). Current status = Alive, but has poor body weight. This snake was originally captured by HA staff while emerging from NH 3 on 04/16/08.

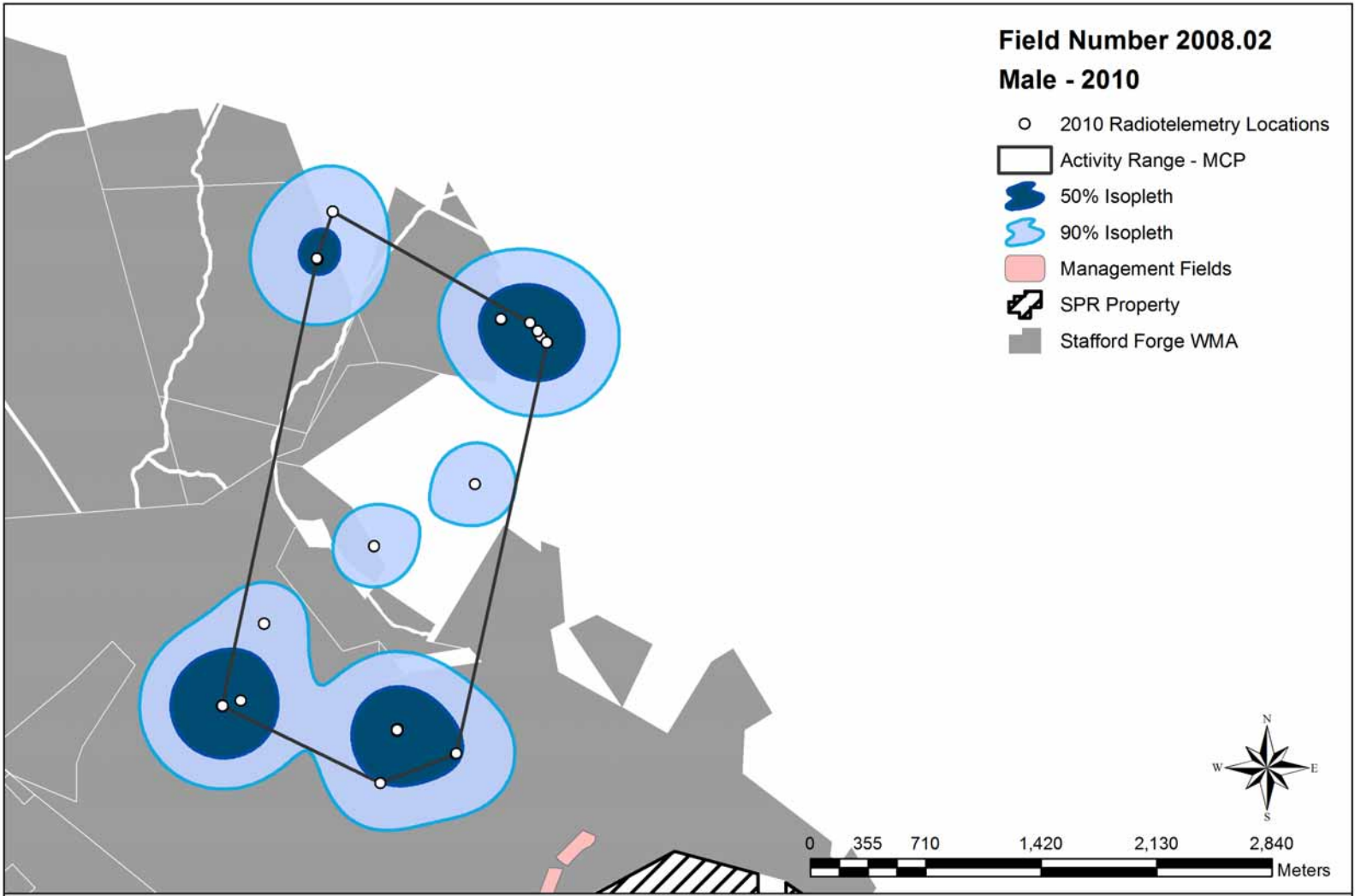
The warm Spring weather in early April brought pine snakes out of their dens and to the surface, so this snake had already egressed from NH 3 prior to the start of radio-tracking on 04/15/10. During the course of the active season, male pine snake 2008.02 was relocated 33 times throughout 2010 (**Figures 35** and **36**). As in previous years, the snake used the upland pine forest along the southeastern side of Hay Road for the remainder of April. On 05/01/10, the snake was taken from the field for radio-transmitter replacement. After surgery and healing, the snake was released back to its last relocation site.

Subsequently, the snake was observed using one of the debris mounds left by the NJ Division of Parks and Forestry after the thinning of the forest along Hay Road. Eventually, the snake made a series of moves to the northwest and across Micaja Road into a portion of upland pine forest the snake was never observed within in prior field seasons. From 09/01/10 to 09/10/10, this snake was concealed in a red squirrel burrow, under the pine cone shuck-pile (squirrel feeding site), at the base of a mountain laurel bush during its shedding cycle (the snake was opaque). On 09/18/10, this snake made a large move north to an area outside its known home range from prior field seasons, to a pine forest along an old power cut. The snake continued north, and on 09/22/10, was relocated in an earth mound less than 10 meters from the shoulder of Route 72. On 09/24/10 the snake was found basking 5 meters from the same busy highway. The snake entered a nearby mammal burrow and did not attempt to cross Route 72.

On 10/02/10, pine snake 2008.02 made a small move west, further away from its home range and hibernacula. HA staff noticed that the snake had poor body weight and did not appear healthy, but no action was taken at this time. On 10/16/10, the snake was relocated at NH 25, that was previously used by pine snake 2007.09 to spend the winter. Over the next couple of relocations this snake was continuously found basking even though the air temperature was cool (~16.5 degrees C.), which is not suitable basking conditions. Also, during this period the snake's overall appearance continued to deteriorate. On 10/20/10 it was decided that the snake was not healthy enough to enter hibernation and survive the winter. It is currently being rehabilitated in HA's laboratory. During this time the snake has gained substantial weight and will be released in the Spring of 2011.



**Figure 35.** Pine Snake 2008.02, coiled by pine branches and leaves, basking on the ground. Note its thin appearance. Photo by Bob Zappalorti, HA.



**Field Number 2008.02  
Male - 2010**

- 2010 Radiotelemetry Locations
- Activity Range - MCP
- 50% Isopleth
- 90% Isopleth
- Management Fields
- SPR Property
- Stafford Forge WMA

**Figure 36.** 2010 activity range of pine snake 2008.02, showing 100% minimum convex polygon (MCP), and 50% and 90% kernel density estimator isopleths (KDE).

|         | Acres   | Hectares |
|---------|---------|----------|
| MCP     | 1104.99 | 447.17   |
| KDE 50% | 250.53  | 101.39   |
| KDE 90% | 1007.61 | 407.77   |

**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.

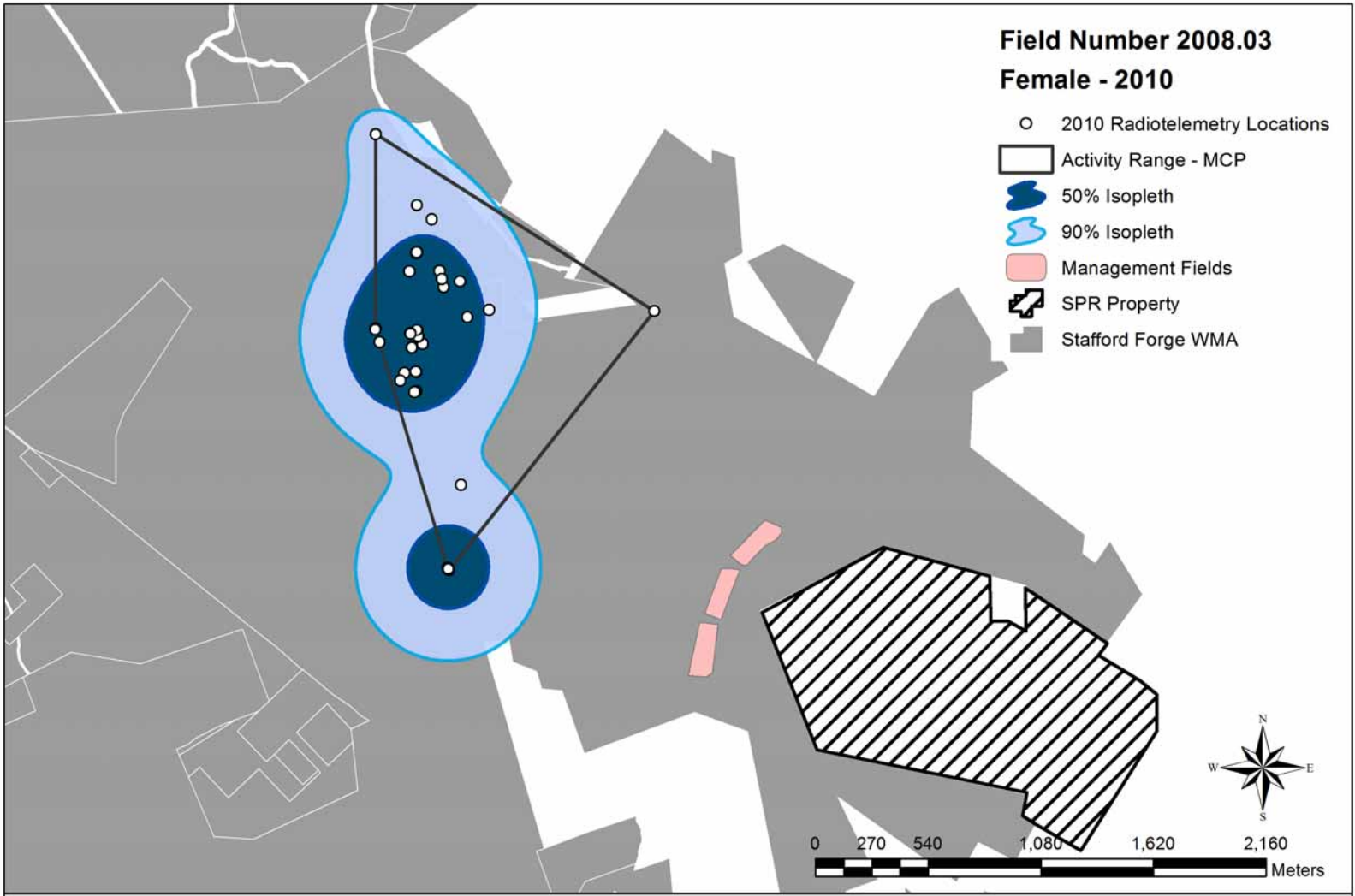
Because of an unusually warm Spring, this snake had already egressed from NH 5 and moved a long distance prior to the start of radio-tracking on 04/15/10. HA was able to relocate this pine snake 59 times throughout the season (**Figure 37**). On the very first day of radio tracking this snake was relocated approximately 1.5 kilometers from its over-wintering site. It was found in a loose coil entangled with a male pine snake (pine snake 2008.08). The male had her clasped behind the head, but let her go after approximately ten minutes. Both snakes then retreated towards a nearby stump-hole.

Unfortunately, HA staff was experiencing a transmitter problem with pine snake 2008.03, and it was pulled from the field for transmitter replacement on it's very first relocation. After being re-implanted it was released into the same stump-hole. Upon release, this snake stayed within the same area of forest for all of April, making small moves possibly searching for a prey item. On 05/05/10, HA staff observed this snake crawling approximately 7 meters up a dead black oak tree (*Quercus velutina*) where it entered a cavity in the side of the tree. The snake's body was seen expanding and contracting, and it was assumed the snake was feeding (see **Figure 7**). Also in early May, the snake used the area of forest selectively thinned by the forestry service along Hay Road. On 05/11/10, the snake was found mating with male pine snake 2009.15, a snake it had mated with the previous year on May 30. However, this snake never appeared to become gravid and was never relocated nesting during the field season.

For the rest of May, the snake was found traveling between the sparsely canopied west side and moderately canopied pine/oak forest on the east side of Hay Road. On 06/13/10, this snake was found inside a mole tunnel. There were two holes leading into the mole tunnel that looked like they had been excavated by the snake. On 06/23/10, this snake made a large move back to the east across the Mill Creek wetland corridor only to return to the selectively thinned forest west of Hay Road prior to the very next relocation. On 07/09/10, the snake entered the forested Mill Creek wetland corridor, a habitat where it had been observed in previous years. The snake was relocated in the wetland or the adjacent upland pine/oak forest until mid September. Like most of the other snakes, this snake was often relocated underground from June through September, most likely due to the very hot and dry weather this past summer.

On 09/15/10, the snake headed back to the south to the cleared forest along Hay Road, where it spent 10 days underground in the vicinity of a stump hole of a very large fallen pine tree. On 09/29/10, the snake was found in NH 5, the same den it used since its capture in 2008, where it remained for the duration of the season. Adult male pine snake number 2006.108 was also sharing the same hibernaculum.





**Figure 37.** 2010 activity range of pine snake 2008.03, showing 100% minimum convex polygon (MCP), and 50% and 90% kernel density estimator isopleths (KDE).

|         | Acres  | Hectares |
|---------|--------|----------|
| MCP     | 350.31 | 141.76   |
| KDE 50% | 133.93 | 54.20    |
| KDE 90% | 502.24 | 203.25   |

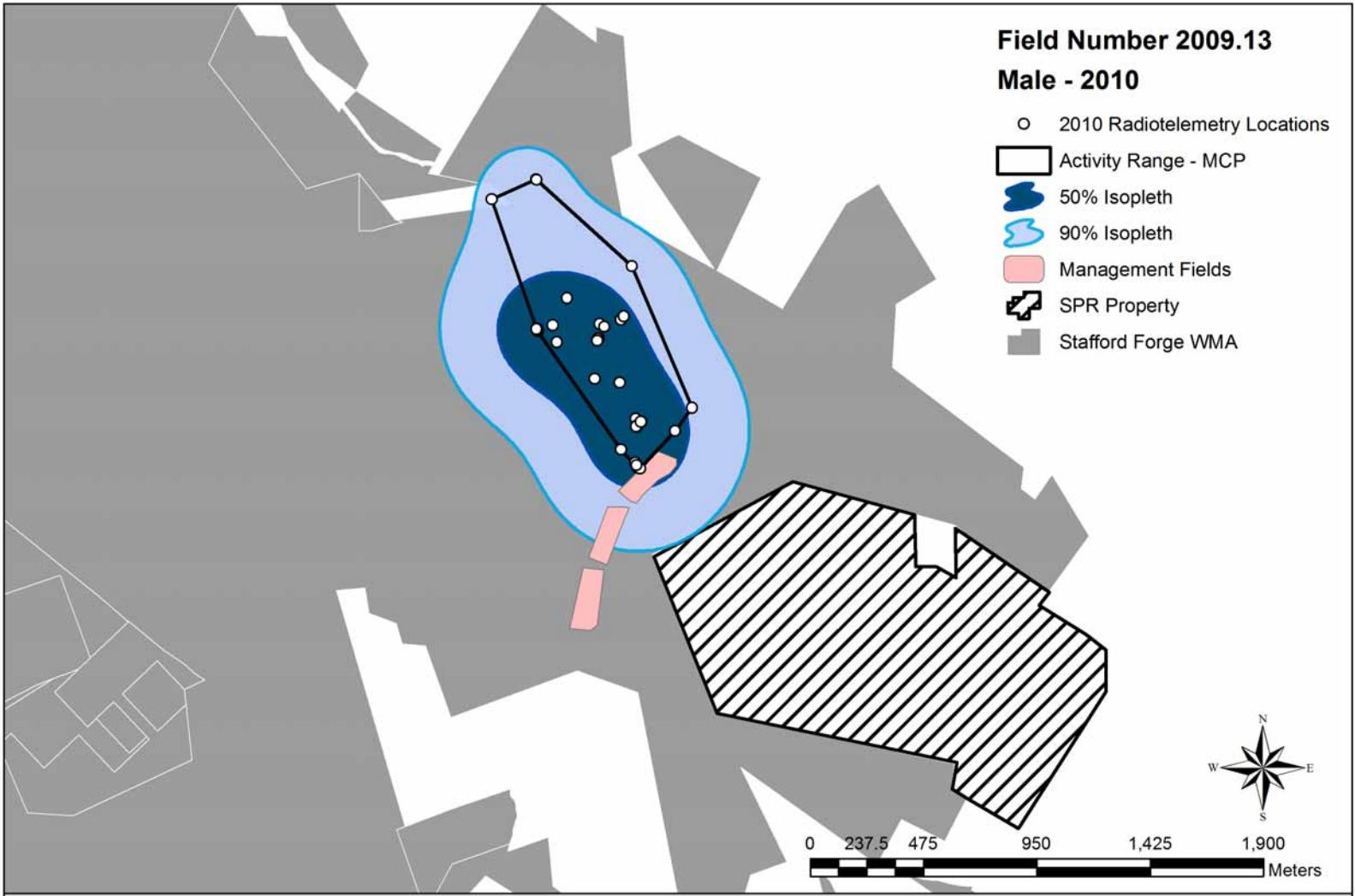
**N. Pine Snake No. 2009.13** (♂). Current status = Alive and healthy. This snake was originally captured by HA staff in trap number 16 of the perimeter drift fence line in early June 2009.

Like most other study snakes, male 2009.13 had already egressed from NH 32 prior to the start of radio-tracking on 04/15/10. This snake was relocated 55 times throughout the season (**Figure 39**). The snake was first found 731 meters southeast of its hibernaculum in the ecotone between the upland pine/oak forest and the Mill Creek wetland corridor. The snake then returned north to the oak/pine forest near the old power cut. It then headed south again, and on 05/01/10, was relocated within 100 meters of MF 6. The snake was then found to be opaque, and used the berm in MF 3 as a shedding station, where it stayed until 05/15/10. The snake then traveled back to the north, where it was seen foraging in the Mill Creek wetland. In early June, this snake returned south and was relocated traveling between the earth mounds along the outer corral path of MF 4 and the upland pine forest near the Hay Road Pond. Throughout July and August, the snake was very rarely seen above ground probably due to the very hot and dry weather conditions.

In September, the snake remained concealed within a mound of dirt along the outer corral path of AH 6 for 2 weeks. The snake then moved north and settled in the root system of a scrub oak (less than 3 meters from the edge of Hay Road) for 4 days, before heading east towards the Hay Road pond. The snake went underground in a mammal burrow a few meters on the south side of Hay Road, near the aforementioned pond on 09/25/10. It was not seen above ground again after this date. This pine snake is currently spending the winter in this newly discovered hibernaculum, which has been designated as NH 40.



**Figure 38.** An example of how Pine Snake 2009.13, can bask and warm its body while remaining partially concealed next to a fallen log on the forest floor. Photo by Bob Zappalorti, HA.



**Figure 39.** 2010 activity range of pine snake 2009.13, showing 100% minimum convex polygon (MCP), and 50% and 90% kernel density estimator isopleths (KDE).

|         | Acres  | Hectares |
|---------|--------|----------|
| MCP     | 114.81 | 46.46    |
| KDE 50% | 107.22 | 43.39    |
| KDE 90% | 353.17 | 142.92   |



## HABITAT USE AND BEHAVIORAL ANALYSIS

Radio-tracking and consistent monitoring of northern pine snakes at the SPR site revealed some interesting habitat use preferences, movements and behaviors. One of the main research questions to be answered by this investigation is to compare the habitat use behavior of the shifted radio-tracked snakes to the non-shifted radio-tracked snakes. **Figures 40** and **41** show two graphs which provide a representation of habitat use and behavioral comparisons of shifted verses non-shifted pine snakes in 2010. **Table 4** provides a breakdown of the forested habitat types used by monitored pine snakes (McCormick 1970 and 1979, Burger and Zappalorti 1989a, Boyd 1991).

For the purpose of this investigation, habitat types used by northern pine snakes in 2010 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).

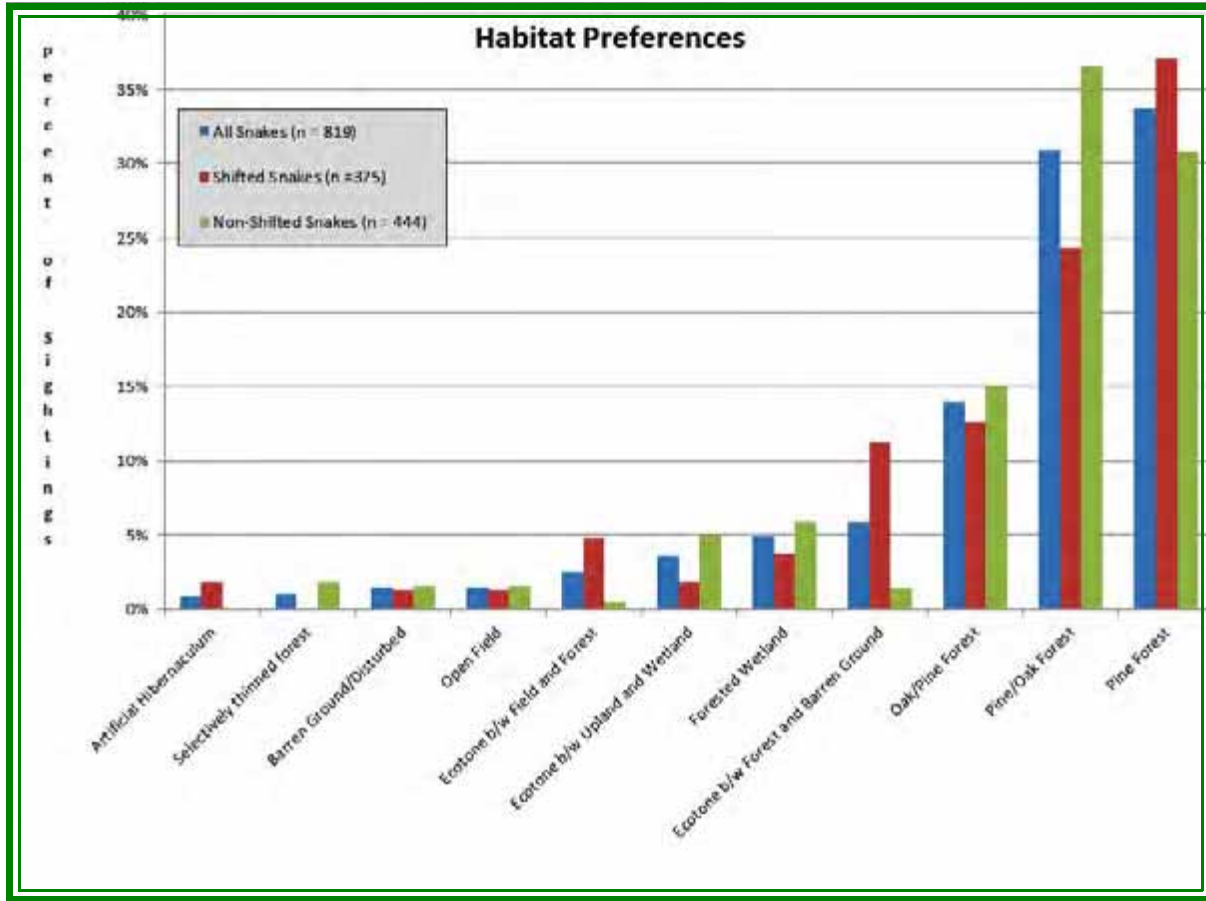
***Pine/Oak Forest*** - pitch pine dominated forest, but containing an oak component.

***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 McCormick (1970 and 1979) and Boyd (1991).

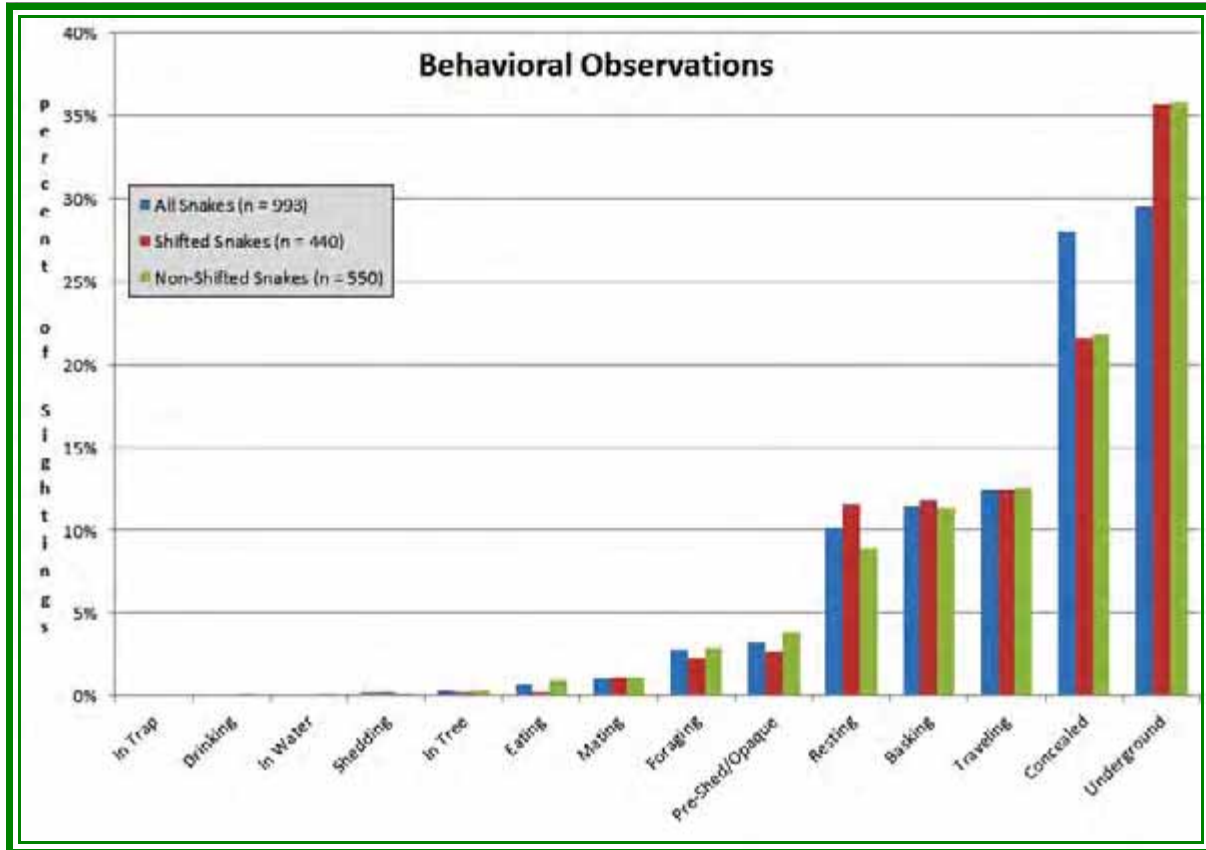


**Figure 40.** For the purpose of this investigation, HA identified 11 different habitat types on the Study Area. This graph represents the frequency of habitats selected by radio-tracked pine snakes by percent.

### *Use of Fire-Altered Habitats*

The response of pine snakes to the May 2007 forest fire-altered habitat was most obvious by their selection of 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 new growth of basal branches. Over the last three-years the forest continued to regenerate and pine snakes are using all suitable habitat types available to them. **Figure 40** along with **Table 4** illustrate the selected habitats used by radio-tracked pine snakes.

In 2010, regeneration of the forest continued rapidly. Although the overstory canopy remained sparse in areas where the fire had crowned and burnt particularly hot in 2007, the understory shrub layer has become a dense mixture of new growth pitch pine, oak saplings, and various shrub species.



**Figure 41.** For the purpose of this investigation, HA identified 14 different behaviors or actions observed while radio-tracking Pine Snakes in their natural habitat. This bar-graph represents the snake’s behavior by the percent of frequency.

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 Plains to the northwest of the site. In addition, the Mill Creek and Cedar Run wetland corridors that bisect the study site have regrown to almost pre-fire density. Regeneration of the overstory in areas where the fire was not severe continues to recover. During 2010, HA staff had to periodically cut back vegetation along the perimeter drift fence to prevent snakes from climbing over the traps and fence (Dargan and Stickel 1949; Enge 1998 and 2001).

***Selective Forest Thinning on Hay and Micaja Roads***

During the fall and winter of 2009 - 2010, the New Jersey Division of Parks and Forests selectively cut and thinned-out areas of pine and pine/oak forests along Hay and Micaja Roads, which run through the study site (see **Figure 8**). 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.



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 is very beneficial to pine snakes and other wildlife. The open canopy provides essential basking habitat while the stump, log and earth mounds provide needed cover and shelter for snakes during the course of their activity season (Friar and Zappalorti 1983). These disturbed open forested areas may also attract more prey items (rodents and birds) due to the edge effect habitat created by the clearing process (Shaw 1970), as well as, the seeds produced by grasses that are able to generate due to the open canopy. Several of the study snakes were relocated using the areas that had been thinned by the forest service on a regular basis during the 2010 field season (refer to Individual Snake Synopses section for more information on snakes using the selectively thinned forests).

**Table 4. Habitat Preferences of Radio-tracked Pine Snakes at Stafford Forge WMA and the Stafford Park Redevelopment Property in 2010.**

| Habitat Types                            | All Snakes (n = 819)  |                  | Shifted Snakes (n = 375) |                  | Non-Shifted Snakes (n =444) |                  |
|--|-----------------------|------------------|--------------------------|------------------|-----------------------------|------------------|
|  | Number of Relocations | Percent of Total | Number of Relocations    | Percent of Total | Number of Relocations       | Percent of Total |
| Artificial Hibernaculum                  | 7                     | 0.85%            | 0                        | 1.87%            | 0                           | 0.00%            |
| Selectively Thinned Forest               | 8                     | 0.98%            | 0                        | 0.00%            | 8                           | 1.80%            |
| Barren Ground/Disturbed                  | 12                    | 1.47%            | 5                        | 1.33%            | 7                           | 1.58%            |
| Open Field                               | 12                    | 1.47%            | 5                        | 1.33%            | 7                           | 1.58%            |
| Ecotone Between Field and Forest         | 20                    | 2.44%            | 18                       | 4.80%            | 2                           | 0.45%            |
| Ecotone Between Upland and Wetland       | 29                    | 3.54%            | 7                        | 1.87%            | 22                          | 4.95%            |
| Forested Wetland                         | 40                    | 4.88%            | 14                       | 3.73%            | 26                          | 5.86%            |
| Ecotone Between Forest and Barren Ground | 48                    | 5.86%            | 42                       | 11.20%           | 6                           | 1.35%            |
| Oak/Pine Forest                          | 114                   | 13.92%           | 47                       | 12.53%           | 67                          | 15.09%           |
| Pine/Oak Forest                          | 253                   | 30.89%           | 91                       | 24.27%           | 162                         | 36.49%           |
| Pine Forest                              | 276                   | 33.70%           | 139                      | 37.07%           | 137                         | 30.86%           |
| <b>Total Relocations</b>                 | <b>819</b>            | ---              | <b>375</b>               | ---              | <b>444</b>                  | ---              |

### THREE EXPERIMENTAL SNAKE TREATMENTS

Only six snakes remained at the end of the 2010 field season from the three original 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 originally 12 snakes (not including hatchlings) in Treatment A, 9 of which were radio-tracked adults. The other three snakes were sub-adults and too small to surgically implant. Instead, they were PIT tagged (Elbin and Burger 1994), placed into the one winter treatments in the fall of 2006, and subsequently released into the wild in 2007. One of these radio-tracked snakes has died each year of the study (2006, 2007, 2008, 2009 and 2010), from either raptor predation, the forest fire, mammalian predation, or other unknown causes (please refer to **Appendix II** for the Deceased Snake Synopsis). At the beginning of the 2010 field season there were three radio-tracked snakes (Pine Snakes 2006.26, 2006.32, and 2006.34) from this treatment that were still alive and accounted for. It was hoped that one other snake from this treatment (pine snake 2006.09) would be relocated during the 2009-2010 winter season. This snake was relocated in late fall of 2009 within a few meters of its known overwintering location when its signal was lost. It was HA's hope that the snake had made an unexpected move to a previously unknown den and that with a concerted effort during the winter season it could be located. However, despite repeated efforts by HA staff to locate this snake during the 2009-2010 winter and the 2010 active field season, it was never found. It is highly doubtful that this snake is still alive. Of the three snakes that were still accounted for at the beginning of the 2010 field season, only one remained by the end. Pine snake 2006.26 went missing in early May and was never relocated afterwards (see individual snake synopses). Pine snake 2006.32's transmitter was found within several meters of its den on the very first day of radio-tracking operations and it is HA's conclusion that raptor predation resulted in the death of this snake (see individual snake synopses above). The only remaining snake at the end of the 2010 field season from the "original" Treatment A radio-tracked snakes is pine snake 2006.34. This snake is currently overwintering in a newly discovered den in upland oak/pine forest southeast of the management fields.

On 05/15/10, 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 that were too small to implant in 2006. After this snake was done mating it was collected by HA staff 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 has 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-tracked portion of the study. Therefore, at the conclusion of the 2010 field season, two pine snakes from this treatment are being actively radio-tracked.

***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 that could not be radio-tracked because it was too small 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 four-year study (please refer to **Appendix II** for the Deceased Snake Synopsis). This leaves only one radio-tracked specimen, female pine snake number 2006.29, as part of the study. In 2010 this snake chose a new natural den in which to overwinter. This den is located in the pine forest west of the management fields and is now known as NH 36.

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

There were originally 8 transmitter implanted adult snakes in Treatment C. These snakes overwintered in HA's laboratory during the 2006 - 2007 winter, due to various health reasons, and were released into AH 1, AH 4, and AH 6 (which were all two winter treatments) in the spring of 2007. By the beginning of the 2010 field season only four snakes (2006.08, 2006.16, 2006.19 and 2006.28) from Treatment C were still being actively radio-tracked. Unfortunately, pine snake 2006.28's transmitter was found in the middle of a wetland corridor on 07/13/10. Although no remains of the snake were found, it is certain that this snake is deceased (see individual snake synopses section). As a result, three snakes still remain from this treatment, two of which (Field Numbers 2006.16 and 2006.19) returned to AH 1 to overwinter and the other (Field Number 2006.08) returned to NH 2, a natural hibernaculum located 30 meters northwest of AH 6.

**NON-SHIFTED PINE SNAKES**

In order to provide a direct comparison with shifted snakes, a control group of non-shifted resident pine snakes have been fitted with radio-transmitters. The behavior and movement patterns of these non-shifted snakes are monitored and recorded simultaneously and via the same methodology as the shifted pine snakes. A total of 9 non-shifted snakes were radio-tracked in 2010, of which six were captured in 2007, two 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 the radio-tracking efforts over the past four field seasons. In 2010, two of these snakes (Field Numbers 2007.11 and 2008.03) returned to the same overwintering sites they used the previous year, and three snakes (Field Numbers 2007.07, 2007.09 and 2009.13) selected new locations. Two of the snakes from this study group are utilizing previously known natural dens, although they are not dens either snake has overwintered in before ( see **Table 6**).



Pine snake 2007.10 is in the den that was used by 2009.13 last season and pine snake 2007.14 is in NH 8, a den that pine snake 2007.11 has hibernated in during every winter of the study. Pine snake 2009.13 chose a new den this winter, a medium sized mammal burrow a few meters into the woods from Hay Road. Pine snake 2007.09 also chose a new den this winter located on an upland ridge west of the Brighton at Barnegat housing development on Route 72. Pine snake 2008.02 is currently in HA's lab due to poor health conditions (please refer to individual snake synopses for more detail). Pine snake 2007.05 is currently missing and its status is unknown (please refer to individual snake synopses for more details). Because of their established activity home ranges and fidelity to their traditional winter dens, none of the non-shifted snakes have selected the artificial hibernacula in which to overwinter.

## **JUVENILE AND HATCHLING PINE SNAKES**

### ***History of Hatchling and Juvenile Pine Snakes (2006 - 2009)***

In 2010 HA staff once again attached traps to the artificial den entrances in April with the intention of capturing any non-radio tracked pine snakes that may have hibernated in them during the winter season. HA staff was hoping to once again observe 2006 hatchlings using the artificial dens. Unfortunately, the traps only produced one pine snake (pine snake 2009.12). It is HA's belief that the majority of the snakes that had overwintered in the artificial dens had already egressed by the time traps were attached to the dens. The first two weeks of April were abnormally warm with temperatures reaching the mid 90's. HA believes that these abnormally high temperatures induced the snakes to leave their den locations earlier than normal. This conclusion is supported by the fact that all of the radio-tracked snakes had egressed from their dens by the time radio-tracking operations had begun on 04/15/10, including the two radio-tracked snakes that had overwintered in AH 1. Also, while affixing traps to the artificial dens, HA staff found a young pine snake under a cover board outside of AH 6. Based on the size of the snake, HA is convinced it was a previously unidentified hatchling from a 2009 clutch. This snake was processed, PIT tagged and released back under the cover board. Finding this young snake outside the den so early in the season further reinforced our theory that the snakes came out of hibernation much earlier than normal.

### ***2006 Hatchlings***

Despite not capturing any 2006 hatchlings in the artificial den traps, one 2006 hatchling (pine snake 2006.41) was recaptured by HA during the 2010 field season. In prior seasons this snake had been recaptured at AH 1, where it was released in 2006. In 2010, this snake was captured by HA crossing Slocum Road approximately 800 hundred meters southwest of the management fields. When this snake was recaptured it had sufficient body weight to be implanted with a one year transmitter and introduced into the radio-tracking study (see Individual Snake Synopses section).

As mentioned earlier, although this snake has a 2006 field number it cannot be considered as part of the 2006 shifted snakes data set. However, HA believes that radio-tracking any of the 2006 hatchlings that can be recaptured will provide important data to the study at the SPR site for several reasons. First of all, it is important to know if the hatchlings that were introduced into the artificial dens successfully imprinted on them. It will also be interesting to determine what home ranges the 2006 hatchlings have established since being released including how far from the management fields they may travel. Also, if HA can capture any of the 2006 female hatchlings, it will be valuable to determine if they imprinted on the management fields as suitable nesting habitat.

### **2007 Hatchlings**

In 2007, HA captured 10 hatchling pine snakes in AH 4 and AH 6. However, none of these 2007 hatchlings were recaptured at the artificial dens in 2009 and 2010, suggesting the snakes may have scent-trailed other conspecifics to natural dens in the forest. The other possibility is that they were killed by predators as survivorship research on hatchling Japanese rat snakes has shown that up to 60% of hatchlings in a cohort do not survive in their first year of life (Fukada 1978 and 1960).

### **2008 Hatchlings**

In 2008, HA captured and PIT tagged 11 new hatchling and juvenile pine snakes. Nine of the snakes were from a nesting/denning location (Natural Hibernaculum 8) south of the SPR property in Stafford Forge WMA. Although, no hatchling snakes with a 2008 field number were recaptured in 2010, the snake found in an artificial den trap at the beginning of the 2010 season was from a 2008 clutch. Even though this snake was definitely from the 2008 cohort (based on its body size when caught) it was not captured until the spring of 2009 when it emerged from AH 1, and that is why it was given a 2009 field number.



**Figure 42.** HA Staff member Matt McCort searching for Pine Snakes and/or their nests on Management Field Two. Photo by Bob Zappalorti.



**Figure 43.** A classic Pine Snake nest found in an open sunny area. Notice the distinct snake trails in the sand-fan and dump-pile. This is typical of the way most Pine Snake excavate their nest burrow. Photo by Bob Zappalorti, HA.

---

### **2009 Hatchlings**

In 2009, HA staff captured and PIT tagged 40 new hatchling and juvenile pine snakes. Three of these new snakes were caught in the artificial den traps during the spring egress. 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) nested on the very top of this earth mound. It is therefore highly likely that this hatchling was from one of those nests. Also, a dead hatchling was found under a small log next to the entrance of one of the aforementioned nests.

However, the vast majority of 2009 hatchling pine snakes came from four different clutches located in a triangle shaped section of disturbed pine forest comprising approximately 127 acres south of the SPR property (See **Appendix IV** for frequently referenced landmarks in Stafford Forge WMA). Two natural dens, multiple pine snake nests and hatchling pine snakes have been observed within this area of forest during this study. A nest was located within this disturbed habitat, via radio-tracked female pine snake 2008.03 in 2009. Upon relocating this snake in her nest, another nest was observed in close proximity.



Both nests were corralled by HA staff in order to PIT tag any hatchlings emerging in the fall. A total of 25 pine snake hatchlings were found in the two enclosures. The nest excavated by female pine snake 2008.03 produced 7 hatchlings.

The other nest produced 18 hatchlings, indicating that two females laid eggs in their own nest chambers, since the mean clutch size of pine snakes is 9 eggs (Zappalorti et al 1983; Burger et al 1988). 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 2010.

As previously mentioned, HA staff did capture what we believe to be a previously unidentified 2009 hatchling under a cover board near AH 6 in April of 2010. This is the only 2009 hatchling that was observed by HA staff in 2010.



**Figure 44.** HA Staff member Matt McCort, holding a gravid female Pine Snake that he captured on Management Field Two. This new snake was released where it was found, so it could deposit her eggs naturally. Photo by Bob Zappalorti, HA.

### ***2010 Hatchling and Juvenile Pine Snakes***

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. The other female 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.



**Figure 45.** An adult female Pine Snake laying an egg in her nest chamber. The eggs are soft and flexible when first laid, but become somewhat hard and leathery within 24-hours. The average clutch is 9-eggs. Photo by Bob Zappalorti, HA.

The nest found 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 gravid female selected and excavated her egg chamber in a drainage gully that descended down a sandy slope from the forest's edge.

Because of the nest location, HA feared that the nest chamber may have flooded during heavy rain events, prior to the eggs hatching. Indeed there were a few periods of torrential rains during the time the eggs were incubating, however the nest never flooded and eventually produced 10 hatchlings in the fall. These snakes were processed by HA and Drexel students and then released outside the corral walls when the experiment was completed. One of these hatchlings was later caught in the perimeter drift fence in an end trap along the management field access road.



**Figure 46.** A hatchling Pine Snake and a second one just cutting its shell with its egg-tooth. Hatchling Pine Snakes usually remain in the nest burrow until after they shed their skin. Photo by Bob Zappalorti, HA.

Since the nest was located within the SPR property, the perimeter drift fence that surrounds the SPR site most likely made it difficult for the hatchlings to access the interior of Stafford Forge WMA. This may have caused the one hatchling from this clutch to become captured in the end trap along the management field access road. It was most likely moving along the fence line trying to find a way into the forest and the first opening in the fence was at the access road. It is unknown whether the other hatchlings from this clutch were successfully able to breach the perimeter fence and gain access to the forest interior, or whether they sought shelter within the SPR property. This question may be answered if any hatchlings survive the winter and are recaptured in 2011.

HA staff also found signs of new hatchlings at the only other known nesting area on the study site which is the landmark known as the “Stafford Triangle.” 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.



## USE OF MANIPULATED AND ENHANCED HABITAT

In 2010, HA once again recorded extensive use of the management fields by the study snakes. Not only has AH 1 been used by two 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. Pine snakes were recorded using the berms for nesting, shedding, foraging and concealment. Some snakes were also located utilizing the earth mounds that line the outer corral paths of dens 1, 4 and 6. In 2010, seven radio-tracked snakes (pine snakes 2006.08, 2006.16, 2006.19, 2006.26, 2006.108, 2007.07, and 2009.13) were relocated in the management fields. The majority of these snakes (71%) were from the “shifted” group. Below are brief descriptions of behavior made when pine snakes were seen utilizing the management fields.

### **Pine Snake 2006.08:**

This snake’s den is in the forest just behind AH 6 and upon egress it spent the first couple of weeks concealed in and along the northern berm of MF 3. It is likely this snake was using the berm for shelter because it was going through a post hibernation shed cycle, as it appeared freshly shed once it emerged from the berm. This snake would return to the same berm for periods of time throughout the active season.

### **Pine Snake 2006.16:**

This snake has overwintered in AH 1 in every year of the study. This snake will travel to oak/pine and pine/oak forest southwest of the management fields to forage during the activity season. However, it has consistently returned 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:**

This may be the one snake that has imprinted on the management fields the most, since it is rarely recorded very far from them. This snake utilized the management fields for all behavioral purposes in 2010. It overwintered in AH 1, was recorded mating along the western berm of MF 2 and nested in the western berm of MF 1. It was found opaque just outside the berms of the management fields and recorded concealed inside the berms while still in a shed cycle. It was also relocated foraging along the edges of the management fields.

**Pine Snake 2006.26:**

Although, this snake overwintered almost 1.7 kilometers southeast of the management fields, upon emergence, this snake was relocated in the berms along the eastern edge of the management fields for the majority of April. In prior field seasons this snake would often travel back and forth to the management fields and into the interior of the forest south/southeast of the management fields. Unfortunately, this snake went missing in early May of 2010. It is not known if the snake would have continued to inhabit the management fields on a consistent basis in 2010 as it had in prior seasons.

**Pine Snake 2006.108:**

This snake was originally recaptured after it was found mating with Pine Snake 2006.19 along the western berm of MF 2. Although, it was not relocated very often in the management fields during the field season, it did spend approximately two weeks in late August concealed in the southwestern corner of the berm in MF 1. In fact, this snake along with 2006.16 and 2006.19 were all concealed within a few feet of each other in the same berm during this period of time.



**Figure 47.** HA Staff member, Michael Zappalorti releasing a Pine Snake after its identification was checked with a PIT Tag reader. The snake was found basking next to AH 1 on MF 1. Photo by Bob Zappalorti, HA.

### **Pine Snake 2007.07:**

In 2010 this snake used the management fields solely for nesting purposes. It spent the majority of the season in pine/oak habitat approximately 1.7 kilometers north of the fields. However, on 06/15/10 it was relocated in the same nest chamber as Pine Snake 2006.19 in the western berm of MF 1. On the next visual relocation the snake was no longer gravid, so it is highly likely she deposited her eggs at this location. This snake was not recorded using the management fields again for the remainder of the field season.

### **Pine Snake 2009.13:**

From 05/04/10 to 05/13/10 it was found in and near the berm along the western edge of MF 3. It was seen in an opaque condition during this time indicating it was using the berm as shelter during its shedding cycle. On 06/07/10 the snake was relocated concealed in one of the earth mounds of the outer corral path of AH 6. Then in early September this snake returned to the vicinity of AH 6 and spent the first two weeks of September concealing itself in the mounds along the outer corral path of AH 6. It was not seen on the surface during this time period so it is unknown whether the snake was in a shedding cycle or not.

## **ENVIRONMENTAL INSPECTIONS AND SITE MONITORING**

Most of the habitat alteration, disturbance and licensed landfill construction on the SPR property was conducted in 2007, 2008 and 2009. Since there was little construction activity in the development areas in 2010, HA was not requested by Walters to monitor any construction activities within the SPR property. However, one of the radio-tracked females (Field Number 2006.29), ventured out onto the western edge of the SPR property and excavated a nesting burrow, laid her eggs, and then returned to the forest (see **Figure 18**). Because of this observation, HA conducted intensive surveys across the SPR site during the nesting season (mid June-mid July). However, no additional pine snake nests were observed on the new landfill or anywhere on the SPR property.

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. 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.





**Figure 48.** The modified lined breeding pond that is known as Retention Basin D. This site has been used by Southern Gray Treefrogs (A.K.A. Cope's Treefrogs), Fowler's Toads and Leopard Frogs as a breeding pond. Photo by Bob Zappalorti, HA.

Monitoring in the Spring of 2010 continued to show that the lined pond is extremely successful in attracting calling male southern gray treefrogs. Although we did not witness any Cope's treefrogs in the mating position (amplexus), during the survey nights, there were 8 to 10 males calling from the edge of the pond.

Once again, no Pine Barrens treefrogs were heard calling directly from the altered habitat on the SPR site. However, during the past two years Pine Barrens treefrogs have been heard calling in natural depressions and wet areas just behind MF 2 during the May - June breeding season. Several Pine Barrens treefrogs were heard calling from wetlands associated with Mill Creek and from the pond off Hay Road during the Spring and Summer of 2010.

#### FORAGING AND FEEDING OBSERVATIONS

The various habitat types on Stafford Forage WMA are rich with birds and small mammal resources which provide an ample food supply for northern pine snakes and other top predators (Reynolds and Scott 1982; Burt and Grossenheider 1980; Fitch 1982 and 1999; Arnold 1993 and Boyd 2000).

Snakes find their prey by following scent trails left by small mammals or birds, then using rapid tongue flicking (Gillingham and Clark 1981). Over the past four-years HA has had the opportunity to observe many different species of small mammals and ground nesting birds which are potential prey items for the pine snake population. Pine snake prey availability and feeding is an important part of population survivorship (Arnold 1993). In prior field seasons HA staff has witnessed the study snakes feeding on various prey items including eastern chipmunks, young cottontail rabbits and white footed mice. In 2010 HA was again fortunate to witness a few of the study snakes successfully subduing and eating wild prey items. Below **Table 5** details feeding observations made by HA staff in 2010.



**Figure 49.** A Meadow Jumping Mouse that was caught in perimeter drift fence. They often live in wet meadows and along streams. Notice the large hind legs and long tail. Photos by Bob Zappalorti.



**Figure 50.** Two Masked Shrews caught in the perimeter drift fence traps. This species appears to be common at Stafford Forge WMA, which serves as prey for hatchling snakes. Photo by Bob Zappalorti.

As part of this investigation, HA operated the large perimeter drift fence trapping system around the SPR property (Enge 1997a and 1997b).

This four-year trapping effort, along with random searching for the target snake species, allowed HA to identify the presence of several small mammal and bird species (Zappalorti et al 2008, Zappalorti et al 2009).



**Figure 51.** An adult White-footed Mouse.

The following species of small mammals were seen on the SPR property and on Stafford Forage WMA study area, or were captured in the perimeter drift fence box funnel traps: short-tailed shrew (*Blarina brevicauda*), masked shrew (*Sorex cinereus* - **Figure 50**), eastern mole (*Scalopus aquaticus*), star-nosed mole (*Cyanocitta cristata*), white-footed mouse (*Peromyscus leucopus* - **Figure 51**), red-backed vole (*Clethrionomys gapperi*), woodland vole (*Pitymys pinetorum*), meadow vole (*Microtus pennsylvanicum*), meadow jumping mouse (*Zapus hudsonius* - **Figure 49**), eastern chipmunk (*Tamias striatus*), red squirrel (*Tamiasciurus hudsonicus*), gray squirrel (*Sciurus carolinensis*) and eastern cottontail rabbit (*Sylvilagus floridanus* - **Figure 52**).





**Figure 52.** A juvenile Eastern Cottontail Rabbit. These rodents serve as important prey items for adult Pine Snakes. Photo by Michael Zappalorti, HA Staff.

---

Stafford Forage WMA has diverse habitat types including pine-oak, oak-pine, wetland sponges, Mill Creek corridor and other forest ecotone uplands. The snake management fields also offer highly suitable habitat for most wildlife species (**Table 5**). Because of the extensive habitat diversity on Stafford Forage WMA, there are rich prey resources available for the pine snake population (Burt and Grossenheider 1952, Reynolds and Scott 1982, Arnold 1993). Additionally, many species of birds also occur at Stafford Forage WMA. Based upon HA's field observations and laboratory feeding experiments, the following birds were confirmed to be eaten by pine snakes: whip-poor-will (*Caprimulgus vociferus*), eastern towhee (*Pipilo erythrophthalmus*), pine warbler (*Dendroica pinus*), wood thrush (*Hylocichla mustelina*), starling (*Sturnus vulgaris*), mourning dove (*Zenaida macroura* - **Figure 53**), American robin (*Turdus migratorius*), ovenbird (*Seiurus aurocapillus*), field sparrow (*Spizella pusilla*) house wren (*Troglodytes troglodytes*), and northern bobwhite eggs and chicks (*Colinus virginianus*). They probably eat many other species of birds, but HA has not witnessed others (Conant and Collins 1991).

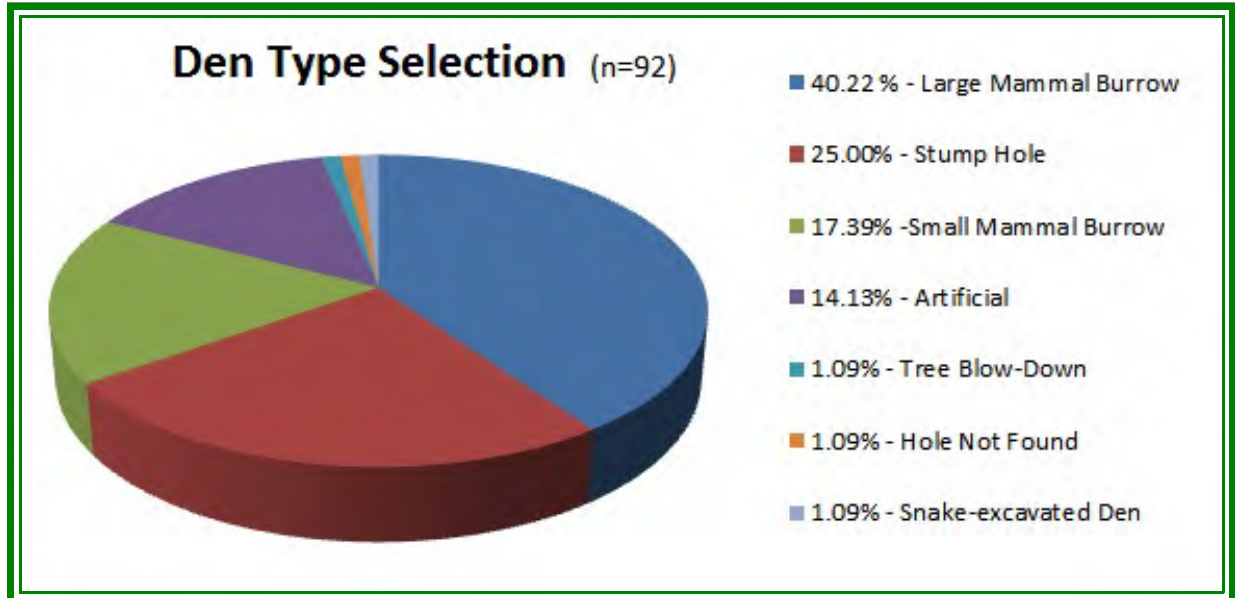


| <b>Table 5. Foraging and Feeding Observations of Pine Snakes in 2010*</b> |                            |                                   |
|---|----------------------------|-----------------------------------|
| <b>Snake ID</b>   | <b>Date of Observation</b> | <b>Species Consumed</b>           |
| 2007.05   | 04/22/10                   | Young White-footed Mice.          |
| 2007.14   | 05/15/10                   | Young Eastern Cottontail Rabbits. |
| 2007.14   | 06/07/10                   | Young Eastern Cottontail Rabbits. |
| 2006.41   | 07/25/10                   | Eastern Mole                      |
| 2007.11   | 08/21/10                   | Whip-poor-will (bird).            |
| 2007.10   | 09/22/10                   | Young Red Squirrels.              |

**\*Refer to the individual snake synopses section for more detailed descriptions of feeding observations.**



**Figure 53.** One of the radio-tracked adult female Pine Snakes that was photographed after it had attacked a Morning Dove nest in a Pitch Pine tree. The snakes body is coiled over the top of the nest (dark area). There were at least three chicks that the snake had eaten. Photo by Bob Hamilton, HA Staff.



**Figure 54.** This Pie-chart graphically identifies the types of winter hibernacula selected by the radio-tracked Pine Snakes, and the percent at which they were used. It includes artificial or human-made dens.

## WINTER AND SUMMER DEN USE

Pine snakes often share their winter dens communally (Carpenter 1953 and 1982, Gregory 1984, Burger et al, 1988). Two adult study snakes (Field Number 2006.16 and 2006.19) from Treatment “C” (snakes that overwintered in HA’s laboratory in 2006), have again returned to AH 1 to spend the winter. These two snakes were released into AH 1 on 04/03/07. They were both forced to overwinter in AH 1, which was a two-winter treatment, during the 2007 - 2008 winter, but then selected and returned to AH 1, by their own choice in the winters of 2008 - 2009 and again in 2009-2010, suggesting the snakes learned to use this site as their den.

As previously mentioned, HA captured one snake (pine snake 2009.12) in the traps attached to the artificial dens in the spring of 2010. This snake was originally captured in an AH 1 trap on 05/13/09. Based on its body size when it was initially captured, HA is certain that this snake is from the 2008 cohort. Another pine snake (2010.01) was found under a cover board at AH 6 as the traps were being affixed to the den entrances. It is HA’s opinion that this snake hatched out in 2009. None of the 2006 hatchlings that were introduced into the artificial dens were captured in the traps in 2010. As previously mentioned, this does not mean that none of the 2006 hatchlings returned to the dens during the 2009-2010 winter. Due to the unseasonably warm spell in early April, it is likely that any snakes that may had overwintered in the dens had already emerged prior to the traps being attached to each entrance pipe (see **Figure 55**).

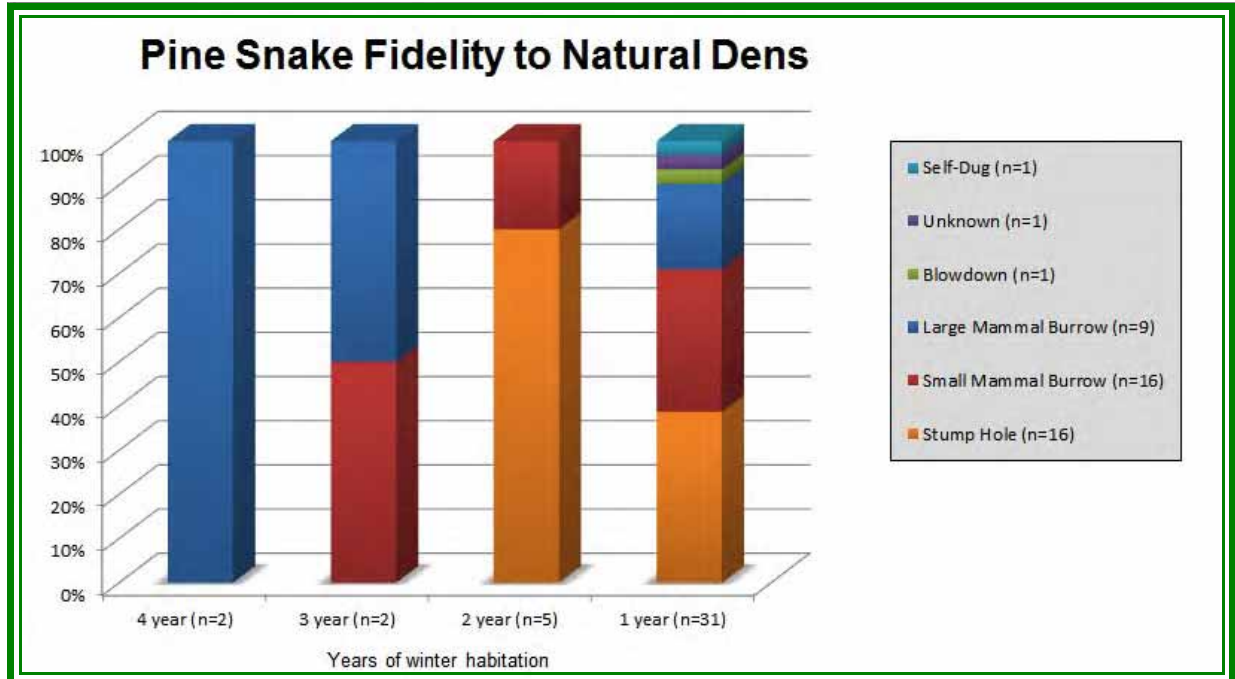


**Figure 55.** Each of the four entrance pipes on the six artificial dens had a special designed snake trap attached to it as shown in this photograph. In the Spring when the snakes emerge from the den, they are forced to crawl into the trap. HA plans to trap all the dens on the Management Fields again in the Spring of 2011. Photo by Dave Schneider, HA Staff.

The fact that HA has recorded neonates using the dens over the past two winters, shows that both hatchlings and adults pine snakes recognize that the artificial dens are suitable overwintering locations. The neonates are most likely locating the artificial dens by following the scent trail 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 in the past, have overwintered in the man-made dens.

No other snake species were found in the traps attached to the artificial dens, however a hatchling eastern hognose snake was found under a cover board next to AH1 in early October. It is very possible that other snake species may be currently overwintering with pine snakes in the artificial dens, as HA has seen this in the past at other artificial den sites (Burger and Zappalorti 2011, and unpublished data). HA will corral the dens again before the spring of 2011 (**Figure 55**).





**Figure 56.** Free-roaming Pine Snakes have a choice as to which site to hibernate in during the winter. Based upon radio-tracking data collected over a four-year period, large and small abandoned mammal burrows and tree stump-holes were the most frequently used refugia as hibernacula. Source: Herpetological Associates, Inc.

The mid-summer of 2010 produced extraordinarily hot temperatures with very little rainfall. As a result, many pine snakes spent a lot 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 in the habitat during the hotter months, thus suggesting the snakes have learned where suitable refugia are located. HA observed many examples of snake estivation during 2010, especially in July, August and early September.

#### PINE SNAKE FIDELITY TO WINTER DENS

Over the course of the past four-years of radio-tracking pine snakes, HA has found and identified 40 different natural winter hibernacula or dens in Stafford Forge WMA. This is a land-area of approximately 7546.8-acres (or 3054.2-hectares) in size which comprises at least 3 meta-populations. **Figure 56** above, shows a breakdown of these various hibernacula types by category, but in general they fall into three types of natural dens. Whereas **Table 6** chronicles how some snakes showed a fidelity to their winter den, while others voluntarily shifted from one den to another, which the specific reasons are poorly understood.

### *Natural Den Types*

- 1). An old tree stump/root system or tree blow-down.
- 2). A large abandoned mammal burrow.
- 3). A small abandoned mammal burrow.

In addition to natural winter den use by pine snakes, HA has confirmed they will also use artificial (or human-made) underground shelters on a regular basis if they are constructed within their home range (Zappalorti and Reinert 1994). **Figure 54** (on page 73) shows that several of the Stafford Forge WMA study snakes selected artificial dens in which to hibernate even though there were 20 plus natural dens within a one-mile radius. Over the past three-years several radio-tracked pine snakes have selected and hibernated in the artificial dens (see **Table 6**). This was proven by trapping each artificial den in the Spring.

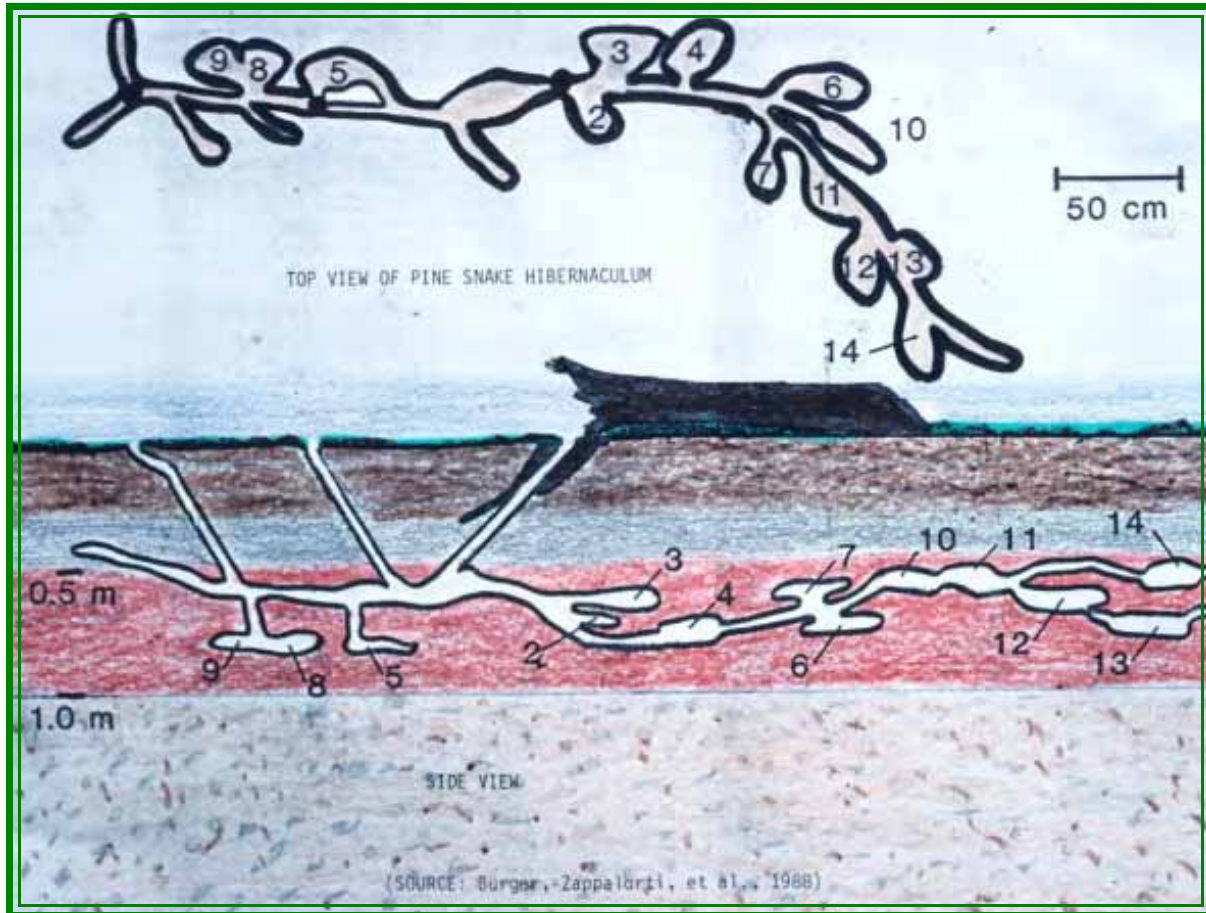
In contrast, pine snake fidelity to natural overwintering sites has been observed to be strongest with respect to large abandoned mammal burrows (Carpenter 1953 and 1982, Gregory 1984, Burger et al, 1988, Zappalorti and Reinert 1994). Radio-tracking has shown that mammal burrows (hibernacula), were the most frequently used natural den type that study snakes selected and returned to every year of the study (**Figure 54**). Over 40% of all den locations selected by the study snakes, through the course of the study... to this point, have been large abandoned mammal burrows. Stump holes with associated old tree root systems were the second most commonly selected natural den types that were used 25% of the time as winter dens (see **Figure 57**). On the other hand, small mammal burrows were used 17.39% of the time by free-roaming pine snakes (see **Table 6**).

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). **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.

**Table 6. Pine Snake Fidelity to (= +) and Shifting from (= →) Winter Dens - 2007 to 2010.**

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





**Figure 57.** A diagrammatic drawing of a natural Pine Snake Hibernaculum that was excavated by Joanna Burger and Bob Zappalorti and drawn to scale. There was one Northern Black Racer and 13 Northern Pine Snakes hibernating in this den. We found three entrances, one at the base of a fallen pine stump and two that went to the surface at 60 cm and 90 cm from the stump hole. The snakes were all down 30 cm from the humus surface, in the B Horizon of the sandy soil (Burger et al, 1988).

## BREEDING AND NESTING OBSERVATIONS

**Female Breeding Observations** - Through intensive monitoring, HA once again observed courtship, mating and nesting behavior of individual pine snakes within the study population in 2010. Although this behavior is rarely witnessed in the wild, radio-tracking has made it possible to observe the mating habits of pine snakes. On several occasions in 2010, HA staff observed breeding behavior between pine snakes. **Table 7** details every breeding observation witnessed by HA staff from 2007-2010. It is interesting to note from the table that many of the snakes appear to breed with the same snake year after year.

***Female Nesting Behavior*** - Multiple nesting activities were observed in June and early July of 2010. Three of the radio-tracked female pine snakes mated and became gravid in 2010. Two of the gravid females nested in the management fields, which is one of their intended purposes. The other female pine snake nested on the western edge of the SPR property. The following is a brief synopsis of nesting behavior that occurred within the management fields during the 2010 nesting season.

1) **Female No. 2006.19**

This shifted female snake was observed mating with three different males during the 2010 field season. After becoming gravid, this snake spent the first week of June concealed in an earth mound along the outer corral path of den 1. Sometime between 06/12/10 and 06/17/10, she laid her eggs in the berm on the western side of MF 1.

2) **Female No. 2007.07**

This non-shifted snake was observed mating twice during the 2010 field season. After becoming gravid, the snake made a large move southwest towards the management fields where it had nested in 2009. On 06/15/10, this snake was observed in the same nest chamber being used by 2006.19. Egg laying occurred sometime before 06/21/10, when she was seen returning to the pine/oak forest where she previously spent several days, but was no longer gravid.

3) **Female No. 2006.29**

This shifted snake was observed mating only once during 2010. In early June, she headed southwest towards the landfill to nest, just as she had done the year before. On 06/15/10, the snake was once again found to have breached the perimeter drift fence, and was concealed under a rusted metal barrel. On 06/15/10, the snake was seen resting on the western edge of the landfill, a few meters from an obvious nest excavation. The snake was inside the nest chamber on the next two relocations, before returning to the forest of the Stafford Forge WMA. This nest was corralled by HA staff and students from Drexel University. Ten healthy pine snake hatchlings were seen within the enclosure in early September, of which all were permanently PIT tagged. If any of these marked hatchlings are recaptured in the future HA may be able to determine survivorship of these 10 neonate pine snakes.

**Table 7. Courtship and Breeding Observations of Pine Snakes between 2007-2010.**

| <b>Snake ID</b>     | <b>2007</b>  | <b>2008</b>   | <b>2009</b>   | <b>2010</b>  |
|---------------------|--|---|---|--|
| 2006.19<br>(Female) | None observed  | None observed   | None observed   | Recorded breeding with Pine Snakes 2006.16, 2006.108, and unknown male.                      |
| 2006.29<br>(Female) | None observed  | None observed   | Recorded breeding with Pine Snake 2007.10.  | Recorded breeding with Pine Snake 2007.10.   |
| 2006.34<br>(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 also recorded breeding with an unknown female. |
| 2006.108<br>(Male)  | N/A  | N/A   | N/A   | Recorded breeding with Pine Snake 2006.19.   |
| 2007.04<br>(Female) | N/A  | None observed.  | Observed being scent trailed by unknown male, but was not observed breeding. However, it did become gravid. | N/A  |
| 2007.05<br>(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.   |
| 2007.07<br>(Female) | N/A  | None observed.  | Never observed breeding, but became gravid.   | Recorded breeding with Pine Snake 2007.10.   |
| 2007.10<br>(Male)   | N /A   | None observed.  | Recorded breeding with Pine Snake 2006.29.  | Recorded breeding with Pine Snakes 2006.29 and 2007.07.                                      |
| 2007.11<br>(Male)   | N/A  | None observed.  | None observed.  | Observed in courtship behavior with Pine Snake 2007.07. No copulation observed.              |
| 2007.14<br>(Male)   | N/A  | None observed.  | Recorded breeding with an unknown female.   | None observed.   |
| 2007.15<br>(Female) | N/A  | None observed.  | Seen a few feet of Pine Snake 2006.17 during the breeding season, no copulation observed. Snake not gravid. | N/A  |
| 2008.03<br>(Female) | N/A  | N/A   | Scent trailed by Pine Snakes 2008.08 and 2009.15 on two separate occasions. Observed mating with 2009.15.   | Recorded being courted by males 2008.08 and 2009.15. Snake was not gravid.                   |





**Figure 58.** Radio-tracking allowed HA to photograph this pair of adult Pine Snakes mating. Late April and May is when all breeding observations were made over the past four years. Photo by Bob Hamilton, HA Staff.

---

### ***General Nesting Behavior***

Once again the pine snakes that nested in the management fields preferred to lay their eggs in the berms rather than excavate a nest chamber in the soil. This behavior was observed in both 2008 and 2009 (Zappalorti et al 2008, Zappalorti et al 2009). As mentioned above, pine snakes 2006.19 and 2007.07 were located in the same spot in the western berm of MF 1 at the same time during the nesting season. Whether they laid their eggs in the same chamber is unknown. The berms are full of small chambers where a snake could successfully deposit its eggs and each snake could have laid her eggs in two distinct chambers that may have been side by side, rather than together in one chamber.

The fact that female pine snake 2006.29 breached the drift fence that surrounds the SPR site and successfully laid her eggs on the landfill, illustrates that these snakes still have strong fidelity to their traditional nesting sites on the SPR property and that the attempts to restrict them have not entirely succeeded. This snake also attempted to nest on the landfill in 2009.

It will be interesting to see if more females return to the old nesting habitat on the SPR property once the perimeter drift fence is removed. The fact that 2007.07 returned to the management fields this year after nesting there last season further reinforces HA's belief that snakes will continue to imprint on the management fields as suitable nesting habitat.

In previous years, HA staff had observed nesting at an area known as the "Stafford Triangle," which is an open disturbed area with adequate loose soil, 2.5 kilometers southwest of the management fields. Although no nests or nesting pine snakes were observed in this area in 2010, HA staff found evidence that successful nesting had occurred there, but the nest opening had been disturbed by a mammal, covered-up with sand and it was missed. There were several pine snake hatchling shed

skins found in the vicinity of NH 8, where a nest and hatchlings have both been observed during the 2008 and 2009 field seasons (Zappalorti et al 2008, Zappalorti et al 2009). HA staff also found six neonate sheds under a cover board at a nest location discovered last season through radio-tracking efforts.



**Figure 59.** A western view of the perimeter drift fence showing the re-growth of forest vegetation. A box funnel trap can be seen on the right side of the fence. All 126 traps were removed from the fence at the end of 2010 field season. Photo by Bob Zappalorti. HA.



## 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. As shown in **Figure 60**, the warm season grasses continued to thrive throughout 2010. 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 (Ted Gordon, personal communication). These fields provide ground cover and shelter not only for pine snakes, but for other wildlife as well (HA staff, personal observations). 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).



**Figure 60.** An example of the warm season native grasses now growing on the three Pine Snake management fields on Stafford Forge WMA. Photo by Bob Zappalorti, HA.

The earth berms (sand and logs) that surround the management fields provide the snakes with plenty of shelter when they are opaque (shed cycle when they are vulnerable to predators) and also provide habitat for small mammals (Zappalorti et al 2007, 2008 and 2009). It is also likely, that the berms trap in moisture which makes the shedding process easier for the snakes. Preliminary data collected during the first four 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 during every year of the study (Zappalorti et al 2007, 2008 and 2009), Besides pine snakes, HA has also recorded numerous other reptile and amphibian species in the management fields.





**Figure 61.** An adult female Pine Snake swallowing an Eastern Mole. The snake captured and constricted the mole in its underground tunnel as its coils burst through to the surface, then it was consumed. Photo by Bernd Skubowius.

#### **PREY AVAILABILITY FOR PINE SNAKES**

There is an array of habitat types on the Stafford Forage WMA, including the created management fields and the open grasslands on the SPR property. These diverse lands are rich with bird and small mammal resources which provide an ample food supply for northern pine snakes (Reynolds and Scott 1982; Burt and Grossenheider 1980; Fitch 1982 and 1999; Arnold 1993 and Boyd 2000).

During the course of this research project, HA has had the opportunity to observe several of the study snakes constricting and eating small mammals and various nesting birds, which are important prey items for the Stafford Forage WMA pine snake population (Burger and Zappalorti 2011). HA also witnessed several small mammals being eaten during laboratory feeding experiments. The most commonly eaten prey items by the study snakes were eastern mole, white-footed mouse, red-backed vole, eastern chipmunk, eastern cottontail and red squirrel (see **Table 5**).



**Figure 62.** A close-up picture of an adult Red-tailed Hawk. At least one nesting pair has been confirmed in the general vicinity of the three Pine Snake management fields on Stafford Forge WMA. Photo by Matt McCort, HA Staff.

## PREDATION OF PINE SNAKES

Predation of the study snakes remains a major problem during this long-term investigation. On the one hand, HA has observed numerous natural predators and threats to the Stafford Forage WMA pine snake population such as red-tailed hawks (**Figure 62**), and coyotes which otherwise would not have been documented. On the other hand, most of the 2006 shifted snakes from treatments A, B and C, have been lost due to predation by mammals and raptors, in addition to human caused killings which thus hampers data collection from the 25 adult snakes from the original sample size (Burger and Zappalorti 2011).

HA was able to determine the cause of death of most study snakes, but a few specimens have gone missing without explanation. For example in 2010, snake 2006.26 suddenly could not be found. HA had a similar problem with pine snake 2006.28. It is possible large mammals such as coyote or red fox may be killing pine snakes and damaging the radio-transmitters so they are no longer functional. If they swallow the unit and carry it away from the study area, the signal cannot be received by HA's equipment. In a study conducted on Cape Cod (where the habitat and population density is similar to that of the New Jersey Pine Barrens), researchers learned that adult eastern coyotes had an average home range of 29.8 square kilometers (Way et al. 2002), so it is possible that after eating the snake a coyote (or red fox), could have carried the radio-unit too far away from the study site for HA staff to get a signal from the transmitter.

## 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 fourth year of this study, 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 with only four-years of data.

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

**Answer - Yes.** Even though the shifted pine snakes were forced to spend one or two-winters in the artificial dens (following the approved management plan protocol), all of these snakes successfully hibernated in them. After removing the corral walls in the spring of 2008, HA has documented a total of nine pine snakes of varying age classes (adults, juveniles and hatchlings) having successfully overwintered in one, or more, of the six artificial hibernacula. Shifted radio-tracked Pine Snakes 2006.16 and 2006.19 have hibernated in AH 1 every winter of the study since the winter of 2007 - 2008. Since the removal of the corral wall, these snakes have been free to select their old natural dens or new denning locations every winter, yet they have returned to AH 1 at the end of all the active field seasons. It appears to HA staff that these two snakes have recognized AH 1 as a suitable overwintering site. HA has also captured a 2006 hatchling pine snake (2006.41) at AH 1 in consecutive years, showing that it to successfully imprinted on the den as a hibernaculum. HA will continue to trap the artificial den entrances during the spring egress over the course of this investigation in order to further determine if adult and young pine snakes continue to 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.** This is the third winter that the corral walls have not limited movement to and from all the artificial hibernacula. During the 2010 spring emergence, HA once again captured a non-shifted pine snake (2009.12) in one of the AH traps. Since the corral walls were removed from all the artificial dens in 2008 a total of four non-shifted pine snakes (this is excluding all 2006 hatchlings and adults that were shifted into the artificial dens) have been recorded overwintering in the artificial dens. Also, HA noted a young hognose snake beneath a cover board near AH 1 this past fall, so it is possible other species may recognize the dens as suitable overwintering sites. HA will continue to trap the artificial dens during the spring egress in subsequent years to further supplement our data on this selection behavior.



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

**Answer - Inconclusive.** 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 2010, when five out of the six largest home ranges were exhibited by the non-shifted snakes. However, a more indepth analysis will need to be conducted to determine if this difference is statistically significant.

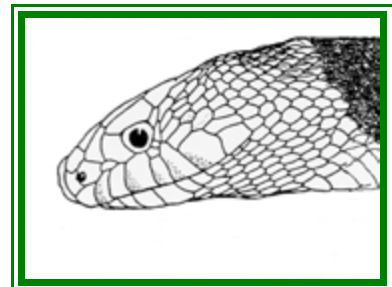
An interesting observation regarding habitat use between the two study groups has been noted during the 2010 field season in the habitat categories of “ecotone between forest and field” and “ecotone between forest and barren ground.” The shifted snakes were observed in these two habitat types over five times as often as the non-shifted snakes. These two habitat types are most often found around the management fields on the SPR study site. It is HA’s observation that shifted snakes used the management fields on a far more regular basis than the non-shifted snakes during the 2010 field season.

Unlike in prior years, in 2010 there were no significant differences observed in the behavioral categories between the shifted and non-shifted pine snakes.

Any concrete conclusions 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.

**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 year of the study a radio-tracked pine snake has been recorded breaching the perimeter drift fence and thus entering the SPR property. Most of these snakes have been gravid females presumably trying to return to their traditional nesting habitat. In 2010, female pine snake number 2006.29 was once again relocated on the SPR property. This snake had breached the perimeter fence in 2009 as well. In 2010 this female was found on the SPR property during the nesting season in late June where she successfully nested on the far western portion of the SPR property.



Interestingly, there was a remarkable drop in the number of snakes relocated moving along the drift fence in 2010, compared to prior years. Only three pine snakes were caught in traps (one was a hatchling from the SPR property nest, one previously unidentified 2010 hatchling and a previously unidentified 3-4 year old snake (probably from the 2006 cohort). This decline could be because most pine snakes that were relocated along the drift fence in prior years, are now deceased or are currently unaccounted for. Other snakes may have learned to avoid the perimeter drift fence and remained in Stafford Forge WMA.

**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 third 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. The only “Treatment Snakes” known to be using the artificial dens during the 2010-2011 winter are the two radio-tracked adults (pine snakes 2006.16 and 2006.19). However, HA will trap the artificial dens during the spring egress of 2011 to record any additional snakes that may be overwintering in them.

**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 has observed both shifted and non-shifted snakes using the management fields to nest. As previously mentioned, two females nested in the western berm of MF 1 in 2010 (one shifted (Pine Snake 2006.19) and one non-shifted (Pine Snake 2007.07). The non-shifted snake (Pine Snake 2007.07) nested in the management fields in 2009 as well. It’s exact nest location in 2009 was unknown, but was likely believed to be in the eastern berm of MF 1. This is the second time that a gravid female study snake has returned to the management fields to nest in consecutive years. This early data suggests that some of the study snakes have imprinted on the management fields as suitable nesting habitat.

**SUMMARY**

In 2010 HA completed the fourth year of the radio-tracking study at the SPR property and surrounding forest. HA continued to record behavior of pine snakes rarely observed in the wild including breeding, foraging, nesting and overwintering behavior. The continued use of the management fields and artificial dens by both shifted and non-shifted snakes shows that some of the snakes have definitively recognized the fields as suitable nesting, hibernating and foraging habitat. The use of the management fields by snakes for nesting, foraging and overwintering behavior is likely to continue, based upon similar pine snake and corn snake management and conservation studies at the Audubon Sanctuary in western Berkeley Township, Ocean County, New Jersey (Robert Zappalorti, personal observations). Unfortunately, mortalities for many reasons continues to contribute to a decline in the total number of study snakes (Burger and Zappalorti 2011). In 2010, HA again witnessed raptor and mammal predation on the pine snakes. As a result, there are now 16 pine snakes being actively radio-tracked at the end of the 2010 field season. Although, HA can always supplement the non-shifted study set with newly captured snakes, it is impossible to replace the 2006 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 2011. A priority has been set to capture these individuals by den trapping and random searching. The surviving hatchlings from the 2006 cohort (see **Table 8**), that were hatched-out in the laboratory and released into the artificial dens could also be studied (Zappalorti and Golden 2006). While the shifted juvenile snakes are now large enough to radio-track, the 2006 hatchlings cannot be considered part of the “shifted” snake study set (since the hatchlings never had the opportunity to establish a home range and therefore cannot be considered shifted). Nevertheless, 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 see if the 2006 hatchlings have imprinted on the management fields, especially in regards to nesting and overwintering behavior (Zappalorti and Golden 2006).

**Table 8. 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          |
| <b>Three Treatments</b>           |            | <b>13</b>   | <b>12</b>     | <b>4</b>  | <b>71</b>  | <b>100</b> |





**Figure 63.** One of the many Northern Red Salamanders that were caught in the Perimeter Drift Fence traps. This specimen has a partially re-generated tail.



**Figure 64.** A small Red Belly Snake, with a portion of its bright red ventral scales showing. Photos by Bob Hamilton, HA Staff.

In 2010, HA completed the four-year trapping portion of the study and many different species of reptiles and amphibians were captured, including some species that are rarely seen such as northern red salamander, redbelly snake and eastern king snake (see **Figures 63 64** and **65**). All traps that were connected to the drift fence which surrounded the SPR property have been removed and the perimeter drift fence will eventually be dug up and removed by Walters. All snakes will once again have unrestricted access to the SPR property and the new landfill. In 2010, as well as, all previous years of the study, HA has witnessed pine snakes attempting to enter the construction area and/or successfully breaching the fence. Now that the fence is to be removed, it is very likely that some pine snakes (and other species), will be located on the development section of the SPR property during the remaining three-years of the study. As per the approved Management and Conservation plan (Zappalorti and Golden 2006), HA will continue to monitor the Stafford Redevelopment property with all its grasslands, rainwater retention basins, and the commercial and residential development areas for pine snake and other wildlife use.

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 and 2009 have already been submitted, while the 2010 results are contained in this document and submitted herewith. There is much more to be learned over the next 3-years and HA looks forward to continuing this important research and investigation.

*Respectfully submitted,*

***Herpetological Associates, Inc.***

## ACKNOWLEDGMENTS

We wish to thank Ed Walters, Joe Del Duca and Bill Kunze from the Walters organization for their continued support and cooperation on this project. We are especially grateful to all the Herpetological Associates employees and other individuals who have helped us throughout the past four-years with our research and field studies. In particular we thank Tessa Bickhart, Walter Bien, Bill Callaghan, Dave Emma, Ray Farrell, Robert Hamilton, Brian Scott, Dave Schneider, Mike Torocco, Michael Zappalorti and others too numerous to mention. We also wish to thank the New Jersey Department of Environmental Protection, Endangered and Non-Game Species Program's Chief, Dave Jenkins for our permits to conduct this research to study pine snakes and other wildlife. This research was entirely funded by The Walters Homes Group and Herpetological Associates, Inc. There are few sources of funding available for such long-term scientific studies.

---



**Figure 65.** Living up to its common name, an adult Eastern King Snake is constricting and killing an adult Eastern Garter Snake and preparing to swallow it by the head. King Snakes have been regularly caught in the SPR perimeter drift fence every year over the past four trapping seasons. Photo by Matt McCort, HA Staff.

❁ LITERATURE CITED ❁

---

---

- Arnold, S. J. 1993. Foraging theory and prey-size – predator size relations in snakes. *In* R. A. Seigel and J. T. Collins (eds.), Snakes: Ecology and Behavior. McGraw-Hill, Inc., New York, New York. pp. 87-115.
- Boyd, H.P. 1991. A Field Guide to the Pine Barrens of New Jersey: It's Flora, Fauna, Ecology, and Historic Sites. Plexus Publishing, Inc. Medford, New Jersey. 423pp.
- Burger, J. 1989a. Following of conspecifics and avoidance of predator chemical cues by Pine Snakes (*Pituophis melanoleucus*). *J. Chem. Ecol.* 15, 799-806.
- Burger, J. 1989b. Incubation temperature has long-term effects on behavior of young Pine Snakes (*Pituophis melanoleucus*). *Behav. Ecol. Sociobiol.* 24, 201-208.
- Burger, J. 1990. Response of hatchling Pine Snakes (*Pituophis melanoleucus*) to chemical cues of sympatric snakes: *Copeia* 1990, 1160-1163.
- Burger, J. 1991b. Response to prey chemical cues by hatchling pine snakes (*Pituophis melanoleucus*) effects of incubation temperature and experience. *J. Chem. Ecol.* 17, 1069-1078.
- Burger, J. and R. T. Zappalorti. 1986. Nest Site Selection by Pine Snakes (*Pituophis melanoleucus*) in the New Jersey Pine Barrens. *Copeia*, (No. 1):116-121.
- Burger, J. and R. T. Zappalorti. 1988a. Habitat use in free-ranging pine snakes (*Pituophis melanoleucus*) in the New Jersey Pine Barrens. *Herpetologica* 44(1)48-55.
- Burger, J. and R. T. Zappalorti. 1989a. Habitat use by pine snakes (*Pituophis melanoleucus*) in the New Jersey Pine Barrens: individual and sexual variation. *Journal of Herpetology*, 23(1):68-73.
- Burger, J. and R. T. Zappalorti. 1991. Nesting behavior of pine snakes (*Pituophis melanoleucus*) in the New Jersey Pine Barrens. *Journal of Herpetology* 25(2):152-160.



- Burger, J. and R. T. Zappalorti. 1992. Philopatry and nesting phenology of pine snakes (*Pituophis melanoleucus*) in the New Jersey Pine Barrens. *Behavioral Ecology and Sociobiology*. 30:331-336.
- Burger, Joanna and R. T. Zappalorti. 2011 - *In Press*. The Northern Pine Snake (*Pituophis Melanoleucus*) in New Jersey: Its Life History, Behavior and Conservation. In: Reptiles: Biology, Behavior and Conservation. Editor: Kristin J. Baker (ISBN: 978-1-61122-856-4) © 2011 Nova Science Publishers, Inc.
- Burger, J., R. T. Zappalorti and M. Gochfeld. 1987. Developmental effects of incubation temperature on hatchling Pine Snakes *Pituophis melanoleucus*. *Comp. Biochem. Physiol.* 87A, 727-732.
- Burger, J., R. T. Zappalorti, M. Gochfeld and E. DeVito. 2007. Effects of off-road vehicles on reproduction success of pine snakes (*Pituophis melanoleucus*) in the New Jersey Pinelands. *Urban Ecosystems*. Springer Science. 10:275-284.
- Burger, J. and R. T. Zappalorti, J. Dowdell, T. Georgiadis, J. Hill, and M. Gochfeld. 1992. Subterranean predation on pine snakes (*Pituophis melanoleucus*). *Journal of Herpetology*, Vol. 26, No. 3, pp. 259-263, 1992.
- Burger, J., R. T. Zappalorti, M. Gochfeld, W. Boarman, M. Caffrey, V. Doig, S. Garber, B. Lauro, M. Mikovsky, C. Safina, and J. Saliva.. 1988. Hibernacula and summer den sites of pine snakes (*Pituophis melanoleucus*) in the New Jersey Pine Barrens. *Journal of Herpetology* 22(4):425-433.
- Burt, W. H. and R. P. Grossenheider. 1952. *A Field Guide to the Mammals: North America north of Mexico*. Houghton Mifflin Company, New York. 289pp.
- Campbell, H. W. and S.P. Christman. 1982. Field techniques for herpetofaunal community analysis in herpetological communities. *Ed. by Norman J. Scott, Jr., U.S. Dept. of the Interior, Fish and Wildlife Service. Wildlife Research Report No. 13, pp. 193-200.*
- Carpenter, C. C. 1953. A study of hibernacula and hibernating associations of snakes and amphibians in Michigan. *Ecology* 34: 74-80.
- Carpenter, C. 1982. The Bullsnake as an Excavator. *Journal of Herpetology*. 16(4):394-401.
- Conant, R. and J. T. Collins. 1991. A Field Guide to Reptiles and Amphibians: Eastern and Central North America. Houghton Mifflin Co., Boston. 450 pp.

- Casazza, M.L., G.D. Wylie, and C.J. Gregory. 2000. A funnel trap modification for surface collection of aquatic amphibians and reptiles. *Herpetol. Rev.* 31:91-92.
- Dargan, L.M., and W. H. Stickel. 1949. An experiment with snake trapping. *Copeia* 1949:264-268.
- Dodd, Jr., C. K. 1993. Strategies for snake conservation. *In Snakes: Ecology and Behavior*. McGraw-Hill, Inc. New York, New York. Chapter 6, pg. 214.
- Dodd, K. C., and R. A. Seigel. 1991. Relocation, repatriation, and translocation of amphibians and reptiles: are they conservation strategies that work? *Herpetologica* 47(3) 336-350.
- Elbin, S.B. & Burger, J. 1994. Using implantable microchips for individual identification in wild and captive populations. *Bull. Wildlife Soc.* 22, 677-683
- Enge, K. M. 1997a. A standardized protocol for drift fence surveys. Technical Report No. 14. Florida Game and Fresh Water Fish Commission, Tallahassee, Florida. 68 pp.
- Enge, K. M. 1997b. Use of silt fencing and funnel traps for drift fencing. *Herpetol. Rev.* 28:30-31.
- Enge, K. M. 1998a. Herpetofaunal drift-fence survey of steephead ravines in 2 river drainages. *Proc. SE Assoc. Fish Wildlife Agencies* 52:336-348.
- Enge, K. M. 1998b. Herpetofaunal survey of an upland hardwood forest in Gadsden County, Florida. *Fla. Sci.* 61:141-159.
- Enge, K. M. 2001. The pitfalls of pitfall trapping. *Journal of Herpetology.* 35(3):467-478.
- Fitch, H. S. 1949. Road counts of snakes in western Louisiana. *Herpetologica* 5: 87-90.
- Fitch, H.S. 1982. Resources of a snake community in prairie-woodland habitat of northeastern Kansas. *In* N.J. Scott Jr. (ed.), *Herpetological Communities*, pg. 83-97. *Wildlife. Res. Report 13*, U.S. Fish and Wildlife. Serve., Washington, DC.
- Fitch, H.S. 1999. A Kansas Snake Community: Composition and Changes over 50 years. Krieger Publishing Company. Malabar, Florida. 105 pp.
- Fitch, H. S., and H. W. Shirer. 1971. A radio-telemetric study of spatial relationships in some common snakes. *Copeia* 1971:118-128.
- Ford, N.B. 1978. Evidence for species specificity of pheromone trails in two sympatric garter snakes, *Thamnophis*. *Herpetol. Rev.* 9:10.

- Ford, N.B. 1986. The role of pheromone trails in the sociobiology of snakes. *In* Chemical Signals in Vertebrates, Vol.4. D. Duvall, D. Müller-Schwarze, and R.M. Silverstein, eds. New York, Plenum. Pp. 261-278.
- Fukada, H. 1978. Growth and Maturity of the Japanese Rat Snake (*Elaphe climacophora*), *Journal of Herpetology* 12 (3): 269-274.
- Fukada, H. 1960. Biological Studies on the Snakes. Reprinted from the Bulletin of the Kyoto Gakugei University. Ser. B: No. 16, March.
- Frier, J. and R. T. Zappalorti. 1983. Reptile and amphibian management techniques. *Transactions of the North American Wildlife Society*, 40:142-148.
- Gehlbach, F.R., J. F. Watkins, and J.C. Kroll. 1971. Pheromone trail-following studies of typhlopoid, leptotyphlopoid and colubrid snakes. *Behavior* 40:282-294.
- Gerald, G. W., M. A. Bailey and J. N. Holmes. 2006a. Movements and Activity Range Sizes of Northern Pine Snakes (*Pituophis melanoleucus melanoleucus*) in Middle Tennessee. *Journal of Herpetology*, Vol. 40, No. 4 (Dec., 2006), pp. 503-510.
- Gerald, G. W., M. A. Bailey and J. N. Holmes. 2006b. Habitat Utilization of *Pituophis melanoleucus melanoleucus* (Northern Pine Snakes) on Arnold Air Force Base in Middle Tennessee. *Southeastern Naturalist*, Vol. 5, No. 2 (2006), pp. 253-264.
- Gillingham, C. and C. Carpenter. 1978. Snake Hibernation: Construction of and Observations on a Man-made Hibernaculum (Reptilia, Serpentes). *Journal of Herpetology*, 1978 12(4):495-498.
- Gillingham, J.C. and D.L. Clark. 1981. Snake tongue-flicking: transfer mechanics to Jacobson's organ. *Canada Journal of Zoology*. 59: 1651-1657.
- Golden, D.M., and Jenkins, D. 2003. Northern Pine Snake, *Pituophis melanoleucus melanoleucus*. In: *Endangered and threatened wildlife of New Jersey* (B. E. Beans & L. Niles, eds). Rutgers Univ. Press, New Brunswick, New Jersey.
- Golden, D.M., Winkler, P., Woerner, P., Fowles, G., Pitts, W., and Jenkins, D. 2009. Status assessment of the Northern Pine Snake (*Pituophis m. melanoleucus*) in New Jersey: an evaluation of trends and threats. <http://www.esri.com/software/arcgis/arcgisoline/isa-world-bundle.html>.



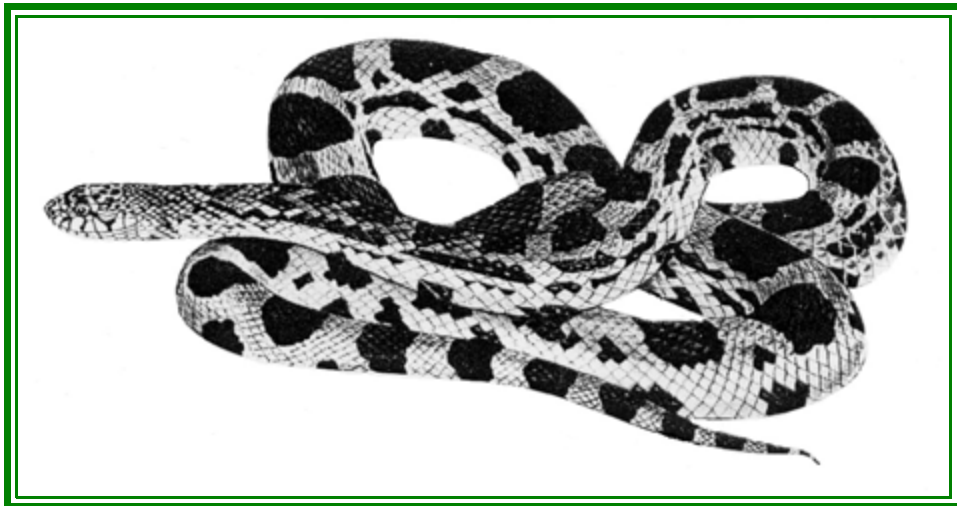
- Graham, R.T., McCaffrey S., Jain T. B, eds. 2004. Science Basis for Changing Forest Structure to Modify Wildfire Behavior and Severity. U.S. Department of Agriculture Forest Service. General Technical Report RMRS-GTR-120. pp 25.
- Greene, H. W. 1997. Snakes: The Evolution of Mystery In Nature. University of California Press, Berkeley and Los Angeles, Ca. pp 121-122
- Gregory, P. T., J. M. McCartney, and K. W. Larsen. 1987. Spatial patterns and movements. P. 336 – 395. In: Snakes: ecology and evolutionary biology. R. A. Seigel, J. T. Collins, and S. S. Novak (Eds.). McMillian Publishing Co. New York, New York.
- Griffith, B., J. M. Scott, J. W. Carpenter, and C. Reed. 1989. Translocation as a species conservation tool: status and strategy. Science 245 (4917) 477-480.
- Heyer, W. R., M. A. Donnelly, R. W. McDiarmid, L. A. C. Hayek, and M. S. Foster (Eds). 1994. Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institution Press, Washington, D. C., USA
- Himes, J. G., L. M. Hardy, D. C. Rudolph, and S. J. Burgdorf. 2006. Movement patterns and habitat selection by native and repatriated Louisiana pine snakes (*Pituophis ruthveni*): implications for conservation. Herpetological Natural History 9(2) 103-116.
- Hooge, P. N., and W. M. Eichenlaub. 1997. Snake movement extension to ArcView. U.S. Geological Survey, Alaska Biological Science Center, Anchorage, Alaska, USA.
- Karns, D. R. 1986. Field herpetology methods for the study of amphibians and reptiles in Minnesota. Published in cooperation with the Nongame Wildlife Program of the Minnesota Dept. of Natural Resources. James Ford Bell Museum of Natural History, Univ. of Minnesota, Occasional Paper No. 18.
- Kauffeld, C. F. 1957. Snakes and Snake Hunting. Hanover House, Garden City, New York. P. 266.
- King, R. B., and K. M. Stanford. 2006. Head starting as a management tool: a case study of the plains garter snake. Herpetologica. 62(3), 282-292.
- King, R., C. Berg, and B. Hay. 2004. A repatriation study of the eastern massasauga (*Sistrurus catenatus catenatus*) in Wisconsin. Herpetologica 60(4) 429-437.
- Kingsbury, B. and J. Gibson, 2002. Habitat management guidelines for amphibians and reptiles of the Midwest. A publication of Partners in Amphibian and Reptile Conservation (PARC). P. 57.

- Lutterschmidt, W. I. 1994. The effect of surgically implanted radio-transmitters upon the locomotory performance of the checkered garter snake, *Thamnophis m. marcianus*. Journal of Herpetology. 4:11-14.
- McCormick, J. 1970. The Pine Barrens. A Preliminary Ecological Inventory. New Jersey State Museum, Trenton, New Jersey.
- McCormick, J. 1979. The Vegetation of the New Jersey Pine Barrens in Forman, R.T.T., ed., Pine Barrens Ecosystem and Landscape. Academic Press, NY.
- Mech, L. D. 1983. Handbook of snake radio-tracking. University of Minnesota Press, Minneapolis, Minnesota, USA.
- Reinert, H. K. 1991. Translocation as a conservation strategy for amphibians and reptiles: some comments, concerns, and observations. Herpetologica 47(3) 357-363.
- Reinert, H. K. 1992. Radio-telemetric field studies of pit vipers: Data acquisition and analysis. In J. A. Campbell and E.D. Brodie, eds. Biology of the Pitvipers, Selva Press, Tyler, Texas., pp. 185-197.
- Reinert, H. K. 1994. Habitat selection in snakes. (In) R. A. Seigel and J. T. Collins (eds.), Snakes: Ecology and Behavior, McGraw-Hill, New York. pp. 201-240.
- Reinert, H. K. and D. Cundall. 1982. An improved surgical implantation method for radio-tracking snakes. Copeia 1982:702-705.
- Reinert, H. K. and R. T. Zappalorti. 1988a. Timber rattlesnakes (*Crotalus horridus*) of the Pine Barrens: their movement patterns and habitat preference. Copeia 1988:964-978.
- Reinert, H. K. and R. T. Zappalorti. 1988b. Field observation of the association of adult and neonatal timber rattlesnakes, *Crotalus horridus*, with possible evidence for conspecific trailing. Copeia 1988:1056-1059.
- Reynolds, R. P. and N.J. Scott, Jr. 1982. Use of a Mammalian Resource by A Chihuahuan Snake Community. In: Herpetological Communities, edited by Norman J. Scott, Jr., U.S. Dept. of the Interior, Fish and Wildlife Service, Wildlife Research Report #13, pp. 99-118.
- Rudolph, C., and S. J. Burgdorf. 1997. Timber rattlesnakes and Louisiana pine snakes of the west Gulf Coastal Plain: hypotheses of decline. Texas J. Science. 49 Supplements:111-122.

- Rudolph, C., S. J. Burgdorf, R. N. Conner, and J. G. Dickson. 1998. The impacts of roads on the timber rattlesnake, (*Crotalus horridus*), in eastern Texas. Proceedings of an International Conference on Wildlife Ecology. Transportation, Ft. Myers, Florida. pp. 236-240.
- Rudolph, C., S. J. Burgdorf, R. R. Schaefer, R. N. Conner and R. T. Zappalorti. 1998. Snake mortality associated with late season radio-transmitter implantation. Herpetological Rev. 29:155-156.
- Samuel, M. D., D. J. Pierce, and E. O. Garton. 1985. Identifying areas of concentrated use within home range. Journal of Snake Ecology 54:711-719.
- Schaefer, W. H. 1934. Diagnosis of sex in snakes. Copeia 1934:181.
- Seaman, D. E., and R. A. Powell. 1996. An evaluation of the accuracy of kernel density estimators for home range analysis. Ecology 77: 2075-2085.
- Shaw, S. 1970. Managing Woodlands for Wildlife. US Department of Agriculture - Forest Service, NE Area State and Private Forestry. 14pp.
- Silverman, B.W. 1986. Density estimation for statistics and data analysis. Chapman and Hall, London, UK.
- Teixeira, C. P., C. S. De Azevedo, M. Meldl, C. F. Cipreste, and R. J. Young. 2007. Revisiting translocation and reintroduction programs: the importance of considering stress. Snake Behavior 73:1-13.
- Tiebout, H. M., and J. R. Carey. 1987. Dynamic spatial ecology of the water snake (*Nerodia sipedon*). Copeia 1997:1-18.
- Tufto, J., R. Anderson, and J. Linnell. 1996. Habitat use and ecological correlates of home range size in a small cervid: the roe deer. Journal of Snake Ecology 65:715-724.
- Vogt, R. C. and R. L. Hine. 1982. Evaluation of techniques for assessment of amphibian and reptile populations in Wisconsin. In: Scott, N.J., editor. Herpetological Communities: A Symposium for the Society for the Study of Amphibians and Reptiles and the Herpetologists League, August 1977. United States Department of the Interior, Fish and Wildlife Service. Wildlife Research Report 13, pp. 201-217.
- Way, J.G., I.M. Ortega and P.J. Auger. 2002. Eastern Coyote Home Range, Territoriality, and Sociality on Urbanized Cape Cod. Northeast Wildlife Vol. 57: 1-18.



- Worton, B. J. 1989. Kernel methods for estimating the utilization distribution in home range studies. *Ecology* 70:164-168.
- Zappalorti, R.T., E.W. Johnson and Z. Leszczynski. 1983. The ecology of the northern pine snake (*Pituophis m. melanoleucus*) in southern New Jersey with special notes on habitat and nesting behavior. *Bull. Chicago Herpetol. Soc.* 18:57-72.
- Zappalorti, R. T. and H. K. Reinert. 1994. Artificial refugia as a habitat-improvement strategy for snake conservation, *In* J. B. Murphy, K. Adler, and J. T. Collins (*eds.*), Captive Management and Conservation of Amphibians and Reptiles. Society for the Study of Amphibians and Reptiles, Ithaca (New York). Contributions to Herpetology, Vol. 11.
- Zappalorti, R. T. and J. Burger. 1985. On the Importance of Disturbed Sites to Habitat Selection by Pine Snakes in the Pine Barrens of New Jersey. *Environmental Conservation*, 12(4):358-361.
- Zappalorti, R. T., and M. E. Torocco. 2002. A Standardized Protocol for Sampling Rare Snakes in the New Jersey Pine Barrens: Critical Habitat Assessment, Survey Techniques, and Trapping Methods. Unpublished report submitted on July 31, 2002, to Carleton Montgomery, Executive Director, The Pinelands Preservation Alliance, 114 Hanover Street, Pemberton, New Jersey 08068. Herpetological Associates, Inc. - Plant and Wildlife Consultants, 575 Toms River Road (Rt. 571), Jackson, New Jersey 08527.
- Zappalorti, R. T. and D. Golden. 2006. Northern Pine Snake Management and Conservation Plan, and Radio-tracking and Monitoring Plan for Stafford Business Park and Stafford Forge WMA. Unpublished report submitted on December 4, 2006, to John Stokes, Executive Director, New Jersey Pinelands Commission. Herpetological Associates, Inc. File No. NJ2006.19-A. Pp. 48.
- Zappalorti, R.T., M. J. McGraw, D.W. Burkett and D. M. Golden. 2008. 2007 Annual Report of Northern Pine Snake Management and Conservation at Stafford Business Park, Stafford Township, Ocean County, New Jersey. Unpublished Report.
- Zappalorti, R.T., M.P. McCort, D.W. Burkett and D. M. Golden. 2009. 2008 Annual Report of Northern Pine Snake Management and Conservation at Stafford Business Park, Stafford Township, Ocean County, New Jersey. Unpublished Report.
- Zappalorti, R.T., M.P. McCort, D.W. Burkett and D. M. Golden. 2010. 2009 Annual Report of Northern Pine Snake Management and Conservation at Stafford Business Park, Stafford Township, Ocean County, New Jersey. Unpublished Report.



# APPENDICES

# APPENDIX I



| <b>Appendix I</b>   |  |  |  |  |  |
|---------------------|--|--|--|--|--|
| <b>Hibernaculum</b> | <b>Field No. of snakes that denned in Hibernaculum (2007-08)</b> | <b>Field No. of snakes that denned in Hibernaculum (2008-09)</b> | <b>Field No. of snakes that denned in Hibernaculum (2009-10)</b> | <b>Field No. of snakes that denned in Hibernaculum (2010-11)</b> | <b>Description of Hibernaculum</b>   |
| 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   | 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   | 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   | 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   | Artificial hibernaculum created by Walters using HA's design. Located on north side of MF 2. |
| AH 5                | None Known   | 2006.46**  | None Known   | None Known   | Artificial hibernaculum created by Walters using HA's design. Located on south side of MF 3. |
| AH 6                | 2006.17, 2006.29   | None Known   | 2010.01****  | None Known   | 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   | Small mammal burrow in pine forest approximately 90 meters west of MF 3.                     |

| <b>Appendix I (Continued)</b> |  |  |  |  |   |
|-------------------------------|--|--|--|--|---|
| <b>Hibernaculum</b>           | <b>Field No. of snakes that denned in Hibernaculum (2007-08)</b> | <b>Field No. of snakes that denned in Hibernaculum (2008-09)</b> | <b>Field No. of snakes that denned in Hibernaculum (2009-10)</b> | <b>Field No. of snakes that denned in Hibernaculum (2010-11)</b> | <b>Description of Hibernaculum</b>  |
| NH 2                          | 2007.03  | 2007.03, 2006.08, 2006.17  | 2006.08, 2009.16***  | 2006.08  | 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   | Large mammal burrow in upland pine forest in SFWMA west of management fields.   |
| NH 4                          | 2006.32  | 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<br>2008.03  | Large mammal burrow in upland pine forest in the interior of SFWMA.   |
| NH 6                          | 2007.09  | 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   | Small mammal burrow leading into earth berm in disturbed pine forest habitat approximately 3.0 km S/SW of the SPR site. |

| <b>Appendix I (Continued)</b> |  |   |  |  |   |
|-------------------------------|--|---|--|--|---|
| <b>Hibernaculum</b>           | <b>Field No. of snakes that denned in Hibernaculum (2007-08)</b> | <b>Field No. of snakes that denned in Hibernaculum (2008-09)</b>  | <b>Field No. of snakes that denned in Hibernaculum (2009-10)</b> | <b>Field No. of snakes that denned in Hibernaculum (2010-11)</b> | <b>Description of Hibernaculum</b>  |
| 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   | Large mammal burrow in disturbed pine forest approximately 100 meters from NH G.  |
| NH 9                          | 2006.09  | 2006.09   | 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   | 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   | 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   | 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. |

| <b>Appendix I (Continued)</b> |  |  |  |  |  |
|-------------------------------|--|--|--|--|--|
| <b>Hibernaculum</b>           | <b>Field No. of snakes that denned in Hibernaculum (2007-08)</b> | <b>Field No. of snakes that denned in Hibernaculum (2008-09)</b> | <b>Field No. of snakes that denned in Hibernaculum (2009-10)</b> | <b>Field No. of snakes that denned in Hibernaculum (2010-11)</b> | <b>Description of Hibernaculum</b>   |
| NH 13                         | 2007.15  | 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   | 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   | 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  | 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   | 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   | 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.   |



| <b>Appendix I (Continued)</b> |  |  |  |  |   |
|-------------------------------|--|--|--|--|---|
| <b>Hibernaculum</b>           | <b>Field No. of snakes that denned in Hibernaculum (2007-08)</b> | <b>Field No. of snakes that denned in Hibernaculum (2008-09)</b> | <b>Field No. of snakes that denned in Hibernaculum (2009-10)</b> | <b>Field No. of snakes that denned in Hibernaculum (2010-11)</b> | <b>Description of Hibernaculum</b>  |
| NH 19                         | None Known   | 2006.28  | None Known   | None Known   | Small mammal burrow in pine/oak forest a considerable distance SW of the SPR site.  |
| NH 20                         | None Known   | 2006.29  | 2006.29, 2009.51***  | None Known   | Stump hole in upland pine forest west of the management fields.   |
| NH 21                         | None Known   | 2007.04  | 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   | 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   | Den is located in unburned upland oak/pine forest approximately six meters in on north side of Hay Road.<br>There was no noticeable entrance hole to den location due to large amount of leaf litter on the forest floor. |

| 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) | Description of Hibernaculum   |
| NH 24                  | None Known  | 2007.15   | 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  | Mammal burrow located on private property near the Brighton Road Development Property on west side of Route 72. Location is approximately 4.4 km NW of the management fields. |
| NH 26                  | None Known  | 2007.10   | 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  | 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  | Large mammal burrow, possibly coyote, in upland pine forest west of Micaja Road.  |

| <b>Appendix I (Continued)</b> |  |  |  |  |  |
|-------------------------------|--|--|--|--|--|
| <b>Hibernaculum</b>           | <b>Field No. of snakes that denned in Hibernaculum (2007-08)</b> | <b>Field No. of snakes that denned in Hibernaculum (2008-09)</b> | <b>Field No. of snakes that denned in Hibernaculum (2009-10)</b> | <b>Field No. of snakes that denned in Hibernaculum (2010-11)</b> | <b>Description of Hibernaculum</b>   |
| NH 29                         | None Known   | None Known   | 2007.05  | 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   | 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  | 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   | Stump hole in upland pine forest west of Hay Road.   |
| NH 33                         | None Known   | None Known   | 2007.07  | None Known   | Cluster of small mammal burrows leading underground in oak/pine forest approx. 1.65 kilometers north of the management fields. |
| NH 34                         | None Known   | None Known   | 2006.34  | None Known   | A nondescript mammal burrow in a pine/oak forest south of the SPR site.  |

| <b>Appendix I (Continued)</b>   |  |  |  |  |  |
|---|--|--|--|--|--|
| <b>Hibernaculum</b>   | <b>Field No. of snakes that denned in Hibernaculum (2007-08)</b> | <b>Field No. of snakes that denned in Hibernaculum (2008-09)</b> | <b>Field No. of snakes that denned in Hibernaculum (2009-10)</b> | <b>Field No. of snakes that denned in Hibernaculum (2010-11)</b> | <b>Description of Hibernaculum</b>   |
| NH 35   | None Known   | None Known   | 2007.10  | 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  | Large mammal burrow.   |
| NH 37   | None Known   | None Known   | None Known   | 2006.34  | Stump hole in upland oak/pine forest south/southeast of the management fields. |
| NH 38   | None Known   | None Known   | None Known   | 2007.07  | Base of a half-fallen pitch pine.  |
| NH 39   | None Known   | None Known   | None Known   | 2007.09,<br>2010.06****  | Large mammal burrow.   |
| NH 40   | None Known   | None Known   | None Known   | 2009.13  | Small mammal burrow.   |
| * Denotes a new snake that was captured in a trap attached to a corralled den in the spring of 2008.  |  |  |  |  |  |
| ** Denotes a new snake that was captured in a trap attached to a corralled den in the spring of 2009. |  |  |  |  |  |
| *** Denotes a new snake that was found basking at a known natural den entrance in the fall of 2009.   |  |  |  |  |  |
| ****Denotes a new snake found trapped or basking at a known den in the spring or fall of 2010.        |  |  |  |  |  |



# **APPENDIX II**

## Appendix II. Deceased Study Snake Synopses:

### Shifted Snakes

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

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

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

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

3) *N. Pine Snake No. 2006.09* (♀). (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 05/20/08 this snake was found killed by an unknown predator along the edge of a wetland corridor west of its previous relocation. The snake had been decapitated and a portion of the upper body was missing. Based on the condition of the carcass (i.e., the cleanly severed backbone and tissue at the wound, rather than stripping of the flesh) suggest mammalian predation. It appeared to have been a recent mortality, since there was no odor emanating from the carcass and rigor mortis had not set in yet. It is possible that the predator that was responsible was scared off by the approach of HA staff before it could finish eating the snake. Because there were just 15 relocations for this snake in 2009, a home range map is not shown.

**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. 2006.27* (♀). (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.

**16) *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.

**17) 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.

**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. This was probably the result of a raptor who tore and peeled strips of flesh from the snake's body in typical bird-of-prey fashion. As additional evidence that a hawk killed the snake, there was a quantity of "whitewash" (white uric acid from a bird) on the trunk of a pine tree and nearby shrubs. Based upon past observations HA suspects a red-tailed hawk was the predator.

**3) 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.

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

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

**5) 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.

**6) *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.

**7) *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**

| <b>Appendix III</b> Hatching Snakes Recaptured Since Initial Release Into Artificial Hibernacula in September 2006. |  |                           |  |  |
|---|--|---------------------------|--|--|
| <b>HA Field Number</b>  | <b>Recaptured in 2007</b>                  | <b>Recaptured in 2008</b> | <b>Recaptured in 2009</b>                  | <b>Recaptured in 2010</b>  |
| 2006.36   | Yes<br>(In AH 6 trap during spring egress) | No                        | No   | No   |
| 2006.37   | No   | No                        | No   | No   |
| 2006.38   | No   | No                        | No   | No   |
| 2006.39   | No   | No                        | No   | No   |
| 2006.40   | Yes<br>(In AH 1 trap during spring egress) | No                        | No   | No   |
| 2006.41   | Yes<br>(In AH 1 trap during spring egress) | No                        | Yes<br>(In AH 1 trap during spring egress) | Yes<br>(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.) |
| 2006.42   | Yes<br>(In AH 5 trap during spring egress) | No                        | No   | Yes  |
| 2006.43   | No   | No                        | No   | No   |
| 2006.44   | Yes<br>(In AH 5 trap during spring egress) | No                        | No   | No   |
| 2006.45   | No   | No                        | No   | No   |
| 2006.46   | No   | No                        | Yes<br>(In AH 3 trap during spring egress) | No   |
| 2006.47   | Yes<br>(In AH 1 trap during spring egress) | No                        | No   | No   |

| <b>Appendix III (Continued)</b> |   |  |                                     |                           |
|---------------------------------|---|--|-------------------------------------|---------------------------|
| <b>HA Field Number</b>          | <b>Recaptured in 2007</b>   | <b>Recaptured in 2008</b>                                  | <b>Recaptured in 2009</b>           | <b>Recaptured in 2010</b> |
| 2006.48                         | Yes<br>(Under cover board near AH 2)  | No   | No                                  | No                        |
| 2006.49                         | No  | Yes<br>(Crawling along perimeter drift fence near trap 55) | Yes<br>(On top of AH 1 on 04/25/09) | No                        |
| 2006.50                         | No  | No   | No                                  | No                        |
| 2006.51                         | No  | No   | No                                  | No                        |
| 2006.52                         | Yes<br>(In AH 2 trap during spring egress)                                  | No   | No                                  | No                        |
| 2006.53                         | Yes<br>(In AH 3 trap during spring egress)                                  | No   | No                                  | No                        |
| 2006.54                         | No  | No   | No                                  | No                        |
| 2006.55                         | No  | No   | No                                  | No                        |
| 2006.56                         | No  | No   | No                                  | No                        |
| 2006.57                         | No  | No   | No                                  | No                        |
| 2006.58                         | Yes<br>(Found dead in the AH 1 outer corral after the May 2007 forest fire) | N/A  | N/A                                 | No                        |
| 2006.59                         | No  | No   | No                                  | No                        |
| 2006.60                         | No  | No   | No                                  | No                        |
| 2006.61                         | No  | No   | No                                  | No                        |

| <b>Appendix III (Continued)</b> |   |                           |                           |                           |
|---------------------------------|---|---------------------------|---------------------------|---------------------------|
| <b>HA Field Number</b>          | <b>Recaptured in 2007</b>                     | <b>Recaptured in 2008</b> | <b>Recaptured in 2009</b> | <b>Recaptured in 2010</b> |
| 2006.62                         | No  | No                        | No                        | No                        |
| 2006.63                         | Yes<br>(In AH 2 trap during spring egress)    | No                        | No                        | No                        |
| 2006.64                         | Yes<br>(In AH 3 trap during spring egress)    | No                        | No                        | No                        |
| 2006.65                         | Yes<br>(Found dead near AH 3. Cause unknown.) | N/A                       | N/A                       | No                        |
| 2006.66                         | No  | No                        | No                        | No                        |
| 2006.67                         | No  | No                        | No                        | No                        |
| 2006.68                         | No  | No                        | No                        | No                        |
| 2006.69                         | No  | No                        | No                        | No                        |
| 2006.70                         | Yes<br>(In the inner corral of AH 6)          | No                        | No                        | No                        |
| 2006.71                         | No  | No                        | No                        | No                        |
| 2006.72                         | Yes<br>(In AH 1 trap during spring egress)    | No                        | No                        | No                        |
| 2006.73                         | Yes<br>(In AH 2 trap during spring egress)    | No                        | No                        | No                        |
| 2006.74                         | Yes<br>(In AH 2 trap during spring egress)    | No                        | No                        | No                        |



| <b>Appendix III (Continued)</b> |   |                           |                           |                           |
|---------------------------------|---|---------------------------|---------------------------|---------------------------|
| <b>HA Field Number</b>          | <b>Recaptured in 2007</b>                     | <b>Recaptured in 2008</b> | <b>Recaptured in 2009</b> | <b>Recaptured in 2010</b> |
| 2006.75                         | No  | No                        | No                        | No                        |
| 2006.76                         | No  | No                        | No                        | No                        |
| 2006.77                         | Yes<br>(In AH 2 trap during<br>spring egress) | No                        | No                        | No                        |
| 2006.78                         | Yes<br>(In AH 1 trap during<br>spring egress) | No                        | No                        | No                        |
| 2006.79                         | Yes<br>(In AH 5 trap during<br>spring egress) | No                        | No                        | No                        |
| 2006.80                         | No  | No                        | No                        | No                        |
| 2006.81                         | No  | No                        | No                        | No                        |
| 2006.82                         | Yes<br>(In AH 2 inner corral)                 | No                        | No                        | No                        |
| 2006.83                         | Yes<br>(In AH 5 trap during<br>spring egress) | No                        | No                        | No                        |
| 2006.84                         | No  | No                        | No                        | No                        |
| 2006.85                         | No  | No                        | No                        | No                        |
| 2006.86                         | Yes<br>(In AH 5 trap during<br>spring egress) | No                        | No                        | No                        |
| 2006.87                         | Yes<br>(In AH 2 trap during<br>spring egress) | No                        | No                        | No                        |
| 2006.88                         | No  | No                        | No                        | No                        |

| <b>Appendix III (Continued)</b> |  |                           |                           |                           |
|---------------------------------|--|---------------------------|---------------------------|---------------------------|
| <b>HA Field Number</b>          | <b>Recaptured in 2007</b>                  | <b>Recaptured in 2008</b> | <b>Recaptured in 2009</b> | <b>Recaptured in 2010</b> |
| 2006.89                         | Yes<br>(In AH 5 trap during spring egress) | No                        | No                        | No                        |
| 2006.90                         | No   | No                        | No                        | No                        |
| 2006.91                         | Yes<br>(In AH 5 trap during spring egress) | No                        | No                        | No                        |
| 2006.92                         | No   | No                        | No                        | No                        |
| 2006.93                         | No   | No                        | No                        | No                        |
| 2006.94                         | No   | No                        | No                        | No                        |
| 2006.95                         | Yes<br>(In AH 3 trap during spring egress) | No                        | No                        | No                        |
| 2006.96                         | Yes<br>(In AH 4 inner corral)              | No                        | No                        | No                        |
| 2006.97                         | No   | No                        | No                        | No                        |
| 2006.98                         | Yes<br>(In AH 6 trap during spring egress) | No                        | No                        | No                        |
| 2006.99                         | No   | No                        | No                        | No                        |
| 2006.100                        | No   | No                        | No                        | No                        |
| 2006.101                        | No   | No                        | No                        | No                        |
| 2006.102                        | No   | No                        | No                        | No                        |
| 2006.103                        | No   | No                        | No                        | No                        |

| <b>Appendix III (Continued)</b> |                             |                           |                           |   |
|---------------------------------|-----------------------------|---------------------------|---------------------------|---|
| <b>HA Field Number</b>          | <b>Recaptured in 2007</b>   | <b>Recaptured in 2008</b> | <b>Recaptured in 2009</b> | <b>Recaptured in 2010</b>   |
| 2006.104                        | Yes<br>(Observed near AH 3) | No                        | No                        | No  |
| 2006.105                        | Yes<br>(Observed near AH 5) | No                        | No                        | No  |
| 2006.106                        | Yes<br>(Observed near AH 1) | No                        | No                        | Yes<br><br>(Snake was captured mating with pine snake 2006.19 next to west berm in MF 2. Snake was implanted with a transmitter.) |

# APPENDIX IV



#### APPENDIX IV: LANDMARK DESCRIPTIONS FOR MAP LEGEND

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

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

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

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

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

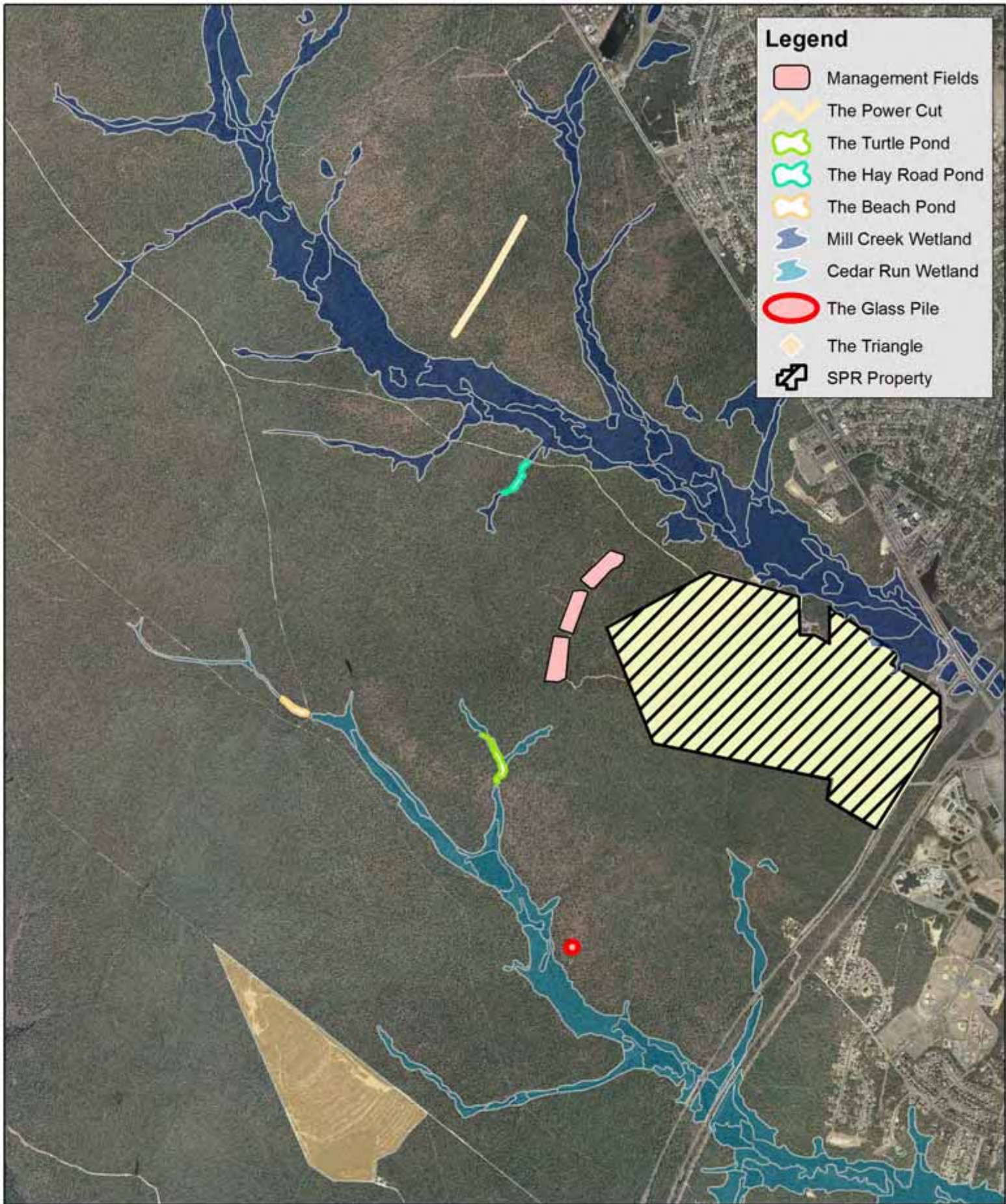
**6. Beach Pond:** A small body of water located west of the SPR site, referenced by the open sandy shore along its eastern edge.

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

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

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

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



**Appendix IV.** Frequently referenced landmarks in Stafford Forge WMA

Source Image: 2007 NJGIN Orthophotography

Herpetological Associates, Inc. 2010

