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ANL-08/10

Movement and Habitat Use of Eastern Hognose Snakes at New Boston Air Force Station, New Hampshire

Environmental Science Division

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prepared by
Environmental Science Division
Argonne National Laboratory

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NOTATION

The following is a list of the acronyms, initialisms, and abbreviations (including units of measure) used in this document.

ACRONYMS, INITIALISMS, AND ABBREVIATIONS

GIS	geographical information system
GPS	global positioning system
INRMP	Integrated Natural Resource Management Plan
MSL	mean sea level
NBAFS	New Boston Air Force Station
PIT	passive integrated transponder
SOPS	Space Operations Squadron
USAF	U.S. Air Force

UNITS OF MEASURE

cm	centimeter(s)
g	gram(s)
ha	hectare(s)
km	kilometer(s)
m	meter(s)
m^2	square meter(s)

MOVEMENT AND HABITAT USE OF EASTERN HOGNOSE SNAKES AT NEW BOSTON AIR FORCE STATION, NEW HAMPSHIRE

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1 INTRODUCTION

The U.S. Air Force (USAF) manages natural resources on New Boston Air Force Station (NBAFS) through the implementation of an Integrated Natural Resource Management Plan (INRMP) (USAF 2006). The NBAFS INRMP supports the military mission of the station by ensuring the long-term sustainability of species, habitats, and ecosystems on NBAFS, and thus proactively avoids conflicts associated with natural resource compliance issues. Natural resources are managed at NBAFS using an adaptive management process that integrates new findings and a developing understanding of human impacts on natural systems into future strategies and plans.

The NBAFS INRMP describes the overall management goals and objectives at NBAFS. It identifies the projects planned over a 5-year period that would be implemented to support those objectives. In the INRMP, goals, objectives, and projects were identified for seven specific natural resource management topical areas, including (1) threatened, endangered, and rare species populations; (2) wetlands; (3) rare natural communities; (4) forest management; (5) control of invasive nonnative plant species; (6) outdoor recreation; and (7) unexploded ordnance remediation.

Goals, objectives, and projects associated with the management of threatened, endangered, and rare species on NBAFS focus on determining distributions, habitat use, and habitat needs; developing management strategies to sustain or improve habitat conditions; and ensuring that populations of these species continue to exist or expand on NBAFS. Three projects were identified in the INRMP that address the status and management of the eastern hognose snake (*Heterodon platirhinos*) on NBAFS:

- Project TE-4.1.1: Continue the monitoring study of eastern hognose snakes to determine seasonal habitat use and movements.
- Project TE-4.1.2: Conduct a radiotelemetry study of adult eastern hognose snakes and determine vegetation, soils, topography, other characteristics, and the ecological context of seasonal habitats and movement corridors.
- Project TE-4.2.1: Develop and implement a management plan for eastern hognose snakes and their habitats.

This report presents and discusses the work conducted on Project TE-4.1.2 in 2006 and 2007. This is the final report for this 2-year project.

The eastern hognose snake is listed by the State of New Hampshire as threatened. It was first positively identified on NBAFS in 1997, and from 1997 through 2004 more than 20 confirmed sightings of the species were made on the station (Kostrzewski et al. 2006). Both adult and juvenile snakes have been observed at the station, and it is known that a reproductive population exists there. The regularity of sightings of eastern hognose snakes on NBAFS and the observation of an individual in a borrow pit reclamation project area indicated that there was a need for a better understanding of movement patterns and habitat use on the station.

Studies of eastern hognose snakes were conducted on NBAFS in 2004 (Najjar and Drake 2005) and 2005 (Kostrzewski et al. 2006). In 2004, systematic searches of known use areas (Boresight Tower and the reclaimed borrow pit) were made to document presence and determine life stage, length, and weight of individual snakes. In 2005, a similar study was conducted with the addition of a test of the feasibility of tracking adult hognose snakes using radiotelemetry. Two adults were surgically implanted with radiotransmitters (one in May and one in September) and tracked for the remainder of the year to determine movement patterns. The adult captured in May made several long-distance movements from its original point of capture (near East Meadow Road in the north central portion of NBAFS), to the central portion of NBAFS (near Joe English Pond; 1 km moved), to the southwestern corner of NBAFS (near the Boresight Tower; 1.8 km moved), and back toward the center of NBAFS (P51 Hill; 1.1 km moved). The second adult moved little after its capture in September near the Boresight Tower (0.3 km moved).

The study objectives in Project TE-4.1.2 included determinations of (1) the overall distribution of the species on NBAFS, (2) the home range size of individuals, (3) movement and activity patterns, and (4) habitat preferences. The results are to be used in making natural resource management decisions and to enable avoidance of impacts on this species that could result from future management or development decisions.

2 DESCRIPTION OF THE STUDY AREA

NBAFS is located in south-central New Hampshire about 19 km west of Manchester. The 1,144-ha site is located within the towns of New Boston, Amherst, and Mont Vernon in Hillsborough County (Figure 1). The 23rd Space Operations Squadron (SOPS), a component of the 50th Network Operations Group, 50th Space Wing, is located at NBAFS, and is the sole military presence at the station. The 23 SOPS provides launch, operation, and on-orbit support for military satellites, communication satellites, and North Atlantic Treaty Organization and other allied nation satellites and for National Aeronautics and Space Administration space shuttle missions.

The NBAFS site is also used for military training exercises. Training activities that have occurred at NBAFS since 1974 include tactical maneuvers (force-on-force exercises), helicopter landing zone deployment, land navigation exercises, emergency response (e.g., simulated vehicle accidents and simulated natural disasters), reconnaissance and combat patrolling, establishment of field camps, and rock climbing and rappelling.

NBAFS is located within an area of hilly and mountainous terrain (USAF 2006). The main physiographic features on NBAFS are Chestnut Hill in the northeastern section, Roby Hill in the southwestern section, and Joe English Hill in the northwestern section. Within the center of the station is Joe English Pond (Figure 1). Elevations on NBAFS range from 104 m mean sea level (MSL) where Joe English Brook exits the southeastern corner of the station to about 389 m MSL at the summit of Joe English Hill (Figure 1).

More than 90% of NBAFS is forested (USAF 2006). Much of the area surrounding NBAFS is rural, with interspersed farms, forests, and residential areas. Land cover on the station is consistent with the surrounding area, and much of the habitat present on the station is represented elsewhere in the county and region. However, residential development of surrounding lands has increased within the past decade, resulting in an increase in the ecological importance of the undeveloped land on NBAFS.

Nine land cover types were delineated on NBAFS during a biodiversity survey (Figure 2; LaGory et al. 1997): mixed forest (46%), coniferous forest (25%), deciduous forest (19%), wetland (3%), oldfield (2%), parkland (developed campgrounds and recreational areas; 2%), open water (Joe English Pond; 2%), developed land (2%), and disturbed land (1%).

Coniferous forest on NBAFS is typically dominated by white pine (*Pinus strobus*) or eastern hemlock (*Tsuga canadensis*). Areas dominated by eastern hemlock usually have little if any vegetation in the understory, but areas dominated by white pine often have relatively diverse understories composed of young deciduous trees, including red oak (*Quercus rubra*), red maple (*Acer rubrum*), and black birch (*Betula lenta*); shrubs such as mountain laurel (*Kalmia latifolia*) and lowbush blueberry (*Vaccinium angustifolium*); and herbaceous species such as Solomon's seal (*Polygonatum pubescens*), bracken fern (*Pteridium aquilinum*), clubmoss (*Lycopodium* spp.), and pipsissewa (*Chimaphila umbellata*). The largest coniferous forest stands are located in the southern portions of NBAFS (Figure 2).

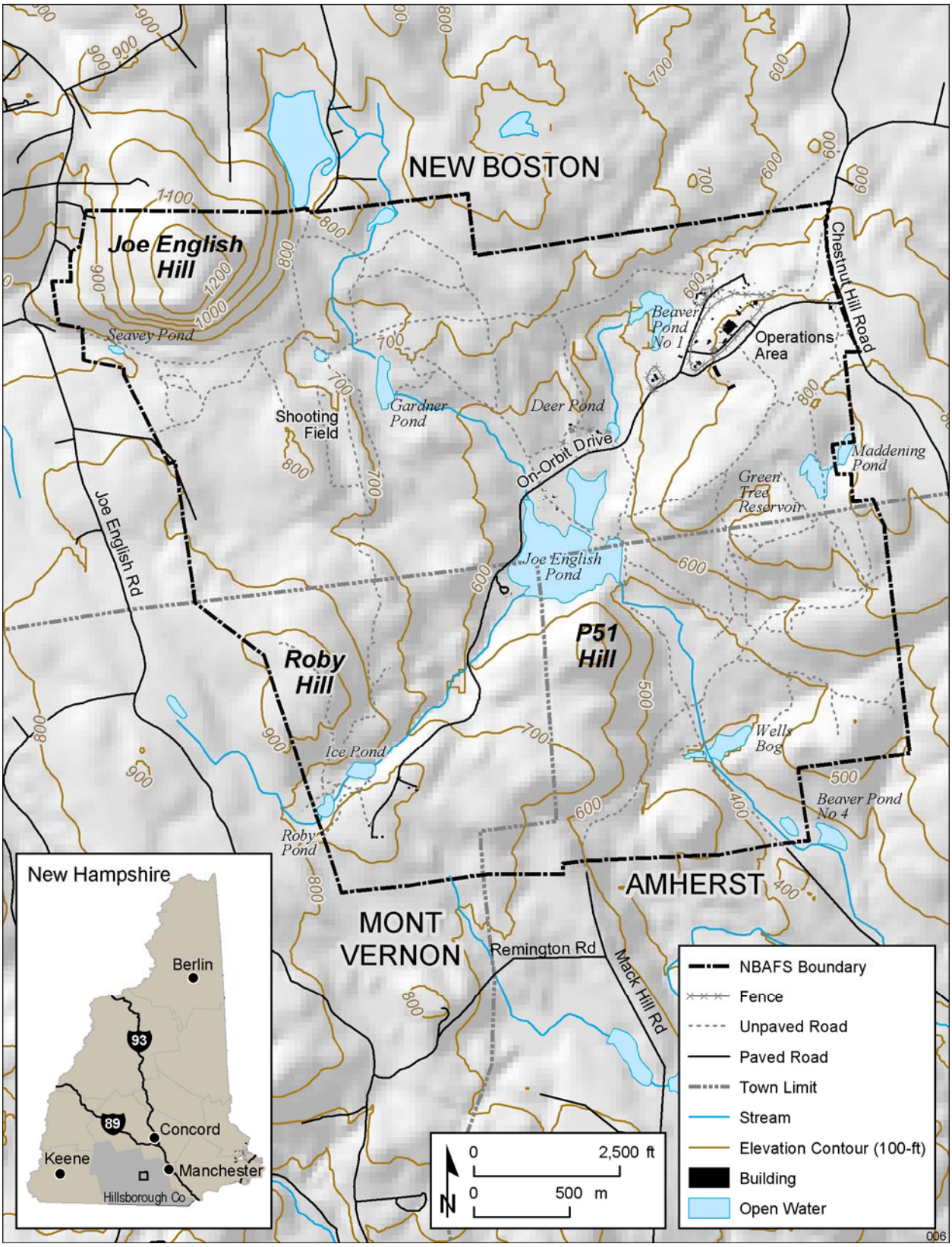


FIGURE 1 Map of New Boston Air Force Station, New Hampshire

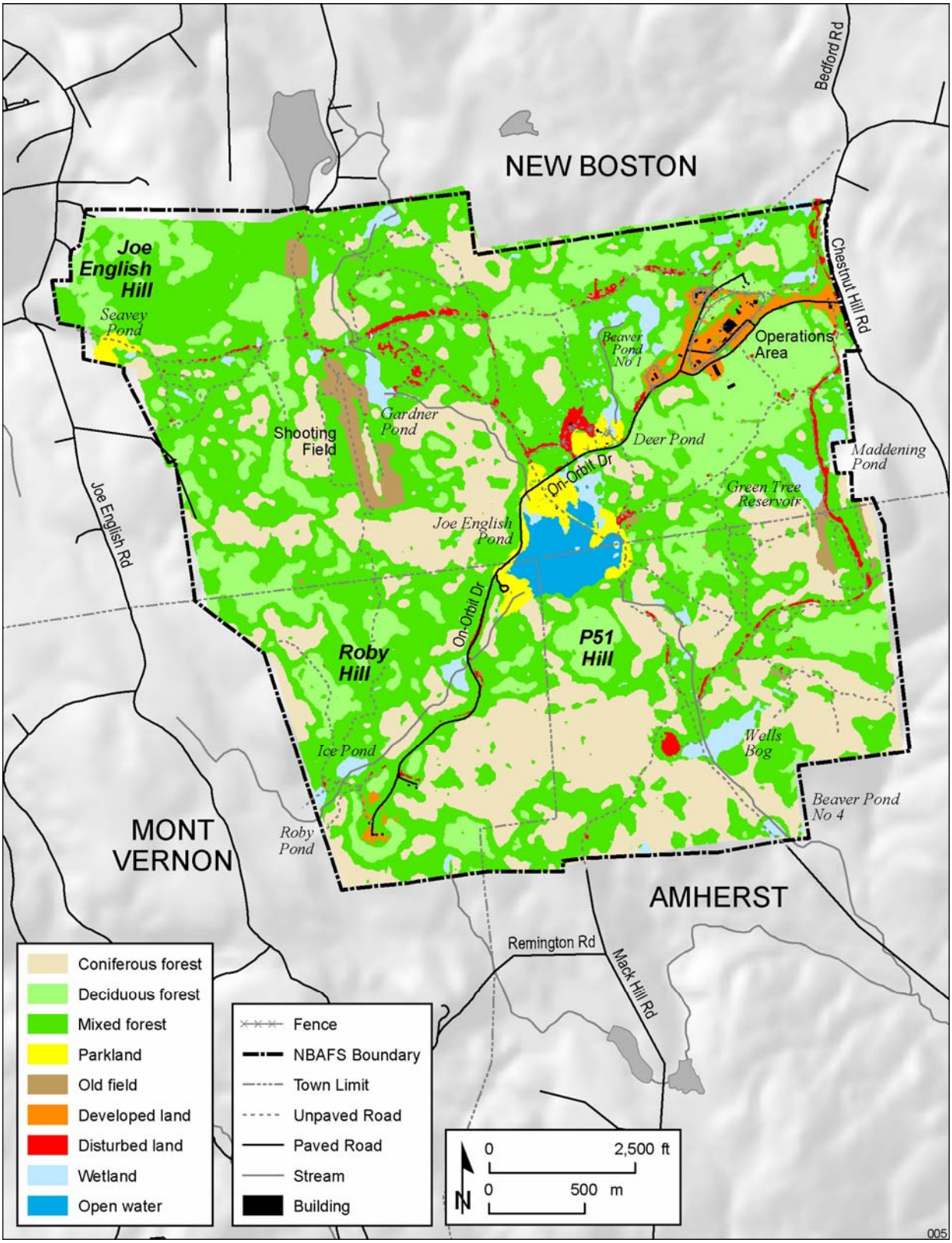


FIGURE 2 Habitat Types of New Boston Air Force Station, New Hampshire (Source: LaGory et al. 1997)

Deciduous forest on NBAFS is dominated by red oak, black oak (*Quercus velutina*), American beech (*Fagus grandifolia*), white ash (*Fraxinus americana*), sugar maple (*Acer saccharum*), red maple, and gray birch (*Betula populifolia*). The understory is typically dominated by saplings of these and other deciduous trees as well as occasional white pine and eastern hemlock; shrubs such as witch hazel (*Hamamelis virginiana*), mountain laurel, and highbush blueberry (*Vaccinium corymbosum*); and herbaceous species such as wild sarsaparilla (*Aralia nudicaulis*), Canada mayflower (*Maianthemum canadense*), starflower (*Trientalis borealis*), clubmoss, wintergreen (*Gaultheria procumbens*), whorled wood aster (*Aster acuminatus*), Indian cucumber root (*Medeola virginiana*), and hay-scented fern (*Dennstaedtia punctilobula*). The largest stands of deciduous forest are located in the northeastern portion of NBAFS (Figure 2).

Mixed forest on NBAFS has a tree canopy composed of a nearly even mix of coniferous and deciduous trees. Mixed forests vary widely in species composition and typically feature a mix of the species found in coniferous and deciduous forests. Mixed forest is the most extensive habitat type on NBAFS (Figure 2).

Oldfields are early successional areas that are usually dominated by grasses and forbs. Most of the oldfield habitat on NBAFS is located in three areas—the Shooting Field, the area south of Green Tree Reservoir, and the area east of Joe English Hill (Figure 2). These areas are periodically mowed or burned to maintain them as early successional habitat. Species found in oldfields on NBAFS include broomgrass (*Andropogon scoparius*), timothy (*Phleum pratense*), meadow fescue (*Festuca pratensis*), New York aster (*Aster novi-belgi*), Queen Anne's lace (*Daucus carota*), goldenrod (*Solidago* spp.), and fireweed (*Erechtites hieracifolia*). Some shrubs and small trees are also scattered throughout oldfields and include autumn olive (*Elaeagnus umbellata*), multiflora rose (*Rosa multiflora*), red maple, paper birch (*Betula papyrifera*), and white pine.

A total of 228 wetlands were identified by Parsons Engineering, Inc. (1996). These wetlands represent a variety of wetland types, including forested, emergent, scrub-shrub, open water, riverine, lacustrine, and mixed wetland types (see Cowardin et al. 1979 for wetland type definitions). Wetland species on NBAFS include cattail (*Typha latifolia*), sedges (*Carex* spp.), rushes (*Juncus* spp.), Virginia chain fern (*Woodwardia virginica*), pitcher plant (*Sarracenia purpurea*), meadowsweet (*Spirea alba*), boneset (*Eupatorium perfoliatum*), button-bush (*Cephalanthus occidentalis*), leatherleaf (*Chamaedaphne calyculata*), sphagnum moss (*Sphagnum* spp.), sweet gale (*Myrica gale*), three-way sedge (*Dulichium arundinaceum*), red maple, and black gum (*Nyssa sylvatica*).

3 METHODS

The study was conducted at NBAFS between May 8 and November 26, 2006, and February 2 and October 22, 2007. Surveys to locate snakes employed a variety of techniques, ranging from opportunistic captures along roads and other areas and intensive habitat searches. Searches were made in areas where snakes had been located in the past as well as in other areas. Visual and aural cues were used to detect snakes, and materials under which snakes could hide (e.g., logs, bark) were checked. Cover sheets made of heavy black plastic (1.5 m × 3 m) and held in place with sod staples or rocks (Kjoss 2000) were placed in a variety of habitats in 2006 and checked in the morning or evening for snakes. No snakes were found below cover sheets in 2006, and the technique was not used in 2007.

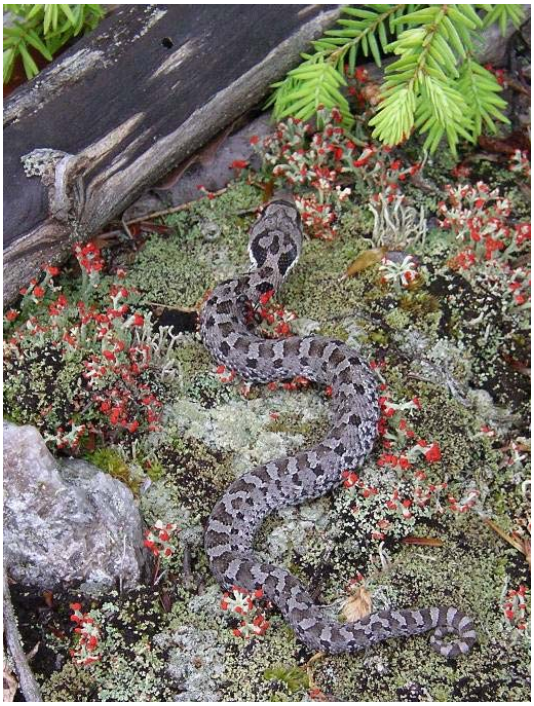
When possible, all eastern hognose snakes captured were weighed, measured, and placed into one of three age categories (adult, juvenile, and hatchling) based on size (hatchlings < 10 g; juveniles between 10 g and 100 g; adults > 100g) (Figures 3 and 4). Adult snakes were sexed by determining the presence or absence of a hemipenis by using a metal probe inserted posteriorly into the cloaca. The sex of individuals was determined by the depth the probe could be easily inserted. In males, the probe could be inserted a distance spanning eight subcaudal scales; in females, the distance spanned fewer subcaudal scales. Most snakes captured, regardless of size, were marked with Passive Integrated Transponder (PIT) tags injected subcutaneously to allow later identification with a PIT tag reader (EZID Mini Multi Mode Tracker, Model 1002). Other data collected for each snake captured included behavior of the snake when first observed, general description of the habitat, and the latitude and longitude as determined using a handheld global positioning system (GPS) receiver (Garmin, Model GPSMap 60C, GPSMap 60CSx, or GPSMap 76Cx). The data collected for each snake are shown in Table 1.

Radiotransmitters were surgically implanted in adult, nongravid, snakes. Radiotransmitters had either an internal coiled antenna (Advanced Telemetry Systems, Model R1170, 4.0 g) or a whip antenna (Model R1680) that was implanted subcutaneously. Adult snakes were transported to Weare Animal Hospital, Weare, New Hampshire, where Dr. Michael Dutton, DVM, implanted transmitters into the snake's abdominal cavity following protocols he used in 2005 and that were described in Kostrzewski et al. (2006). When possible, radiotransmitters were replaced after a year of service using the same surgical procedure.

Snakes with radiotransmitters (referred to in this report as "radiotagged" snakes) were regularly located using a portable receiver (Communications Specialists, Model R-1000) equipped with a three-element yagi antenna (Communications Specialists, Model RA-150). Locations were determined daily during the first week after initial marking, and attempts were made to locate snakes regularly until the snake entered its hibernaculum in the fall. The location of each snake was determined by following the signal to the snake. Visual confirmation of the snake was noted when practical, and the behavior of the snake was also noted. A general description of the site and vicinity was made and the coordinates determined using a handheld GPS receiver. Using a geographic information system (GIS; ArcGIS 9.2), snake locations were displayed and analyzed to determine the distance traveled and home range size. Home range size was calculated using the minimum convex polygon method (Powell 2000). These analyses were

Adult

Juvenile



Hatchling

FIGURE 3 Adult, Juvenile, and Hatchling Eastern Hognose Snakes, New Boston Air Force Station

Determining Weight

Determining Length

Determining Sex

PIT Tagging

FIGURE 4 Collecting Data on and Marking Eastern Hognose Snakes at New Boston Air Force Station

TABLE 1 Data Recorded for Captured Eastern Hognose Snakes at New Boston Air Force Station in 2006 and 2007

Data Collected
Date
Time of day
Location (latitude and longitude)
Snake identification number
PIT tag number
Age class (adult, juvenile, hatchling)
Sex
Weight (g)
Total length or snout-vent length (cm)
Behavior
Habitat description

only performed for snakes with at least 15 locations that spanned the entire active period (May through September).

More detailed information on habitat conditions was collected in October 2006 and September 2007 (Figure 5). Prior to habitat data collection, snake locations for the year were mapped, and a random sample of these snake locations was selected for habitat characterization; additional points on NBAFS were chosen randomly for characterization (Figure 6). The intent of this approach was to determine whether snakes selectively chose locations based on habitat characteristics.

Figure 5. Habitat Data Collection Using 0.25 m^2 Quadrat along Linear Transect.

A linear transect approach was used to quantify habitat conditions. At each sample snake or random location, an 8-m linear transect was placed with its origin at the sample location and oriented in a randomly determined direction. Data were collected in 0.25-m^2 quadrats centered at the transect origin and at every 2-m interval along the transect (Figure 5). Thus, for each transect, data were collected from 5 quadrats (subsamples). The data collected for each sample location are shown in Table 2.

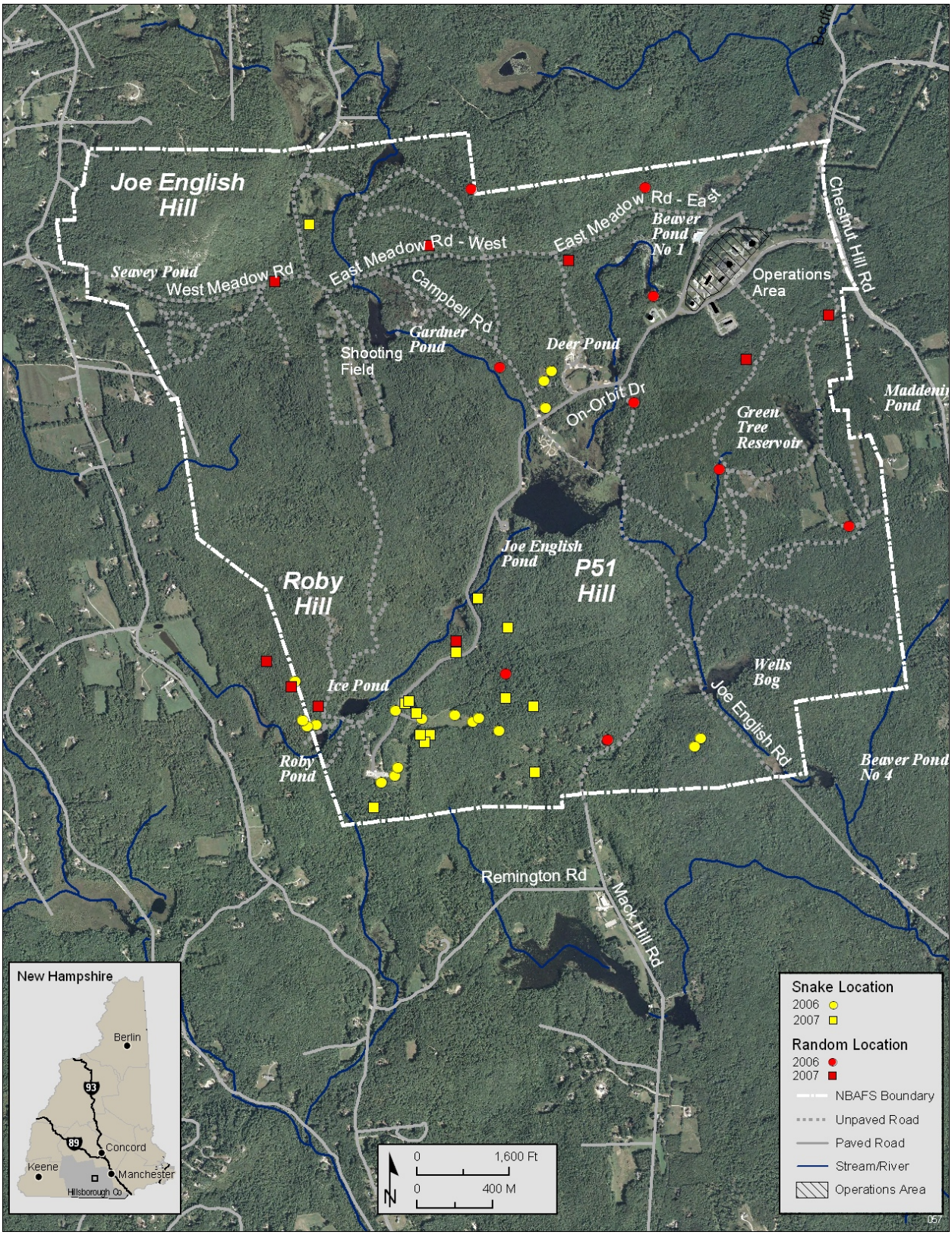


FIGURE 6 Habitat Survey Locations on New Boston Air Force Station in 2006 and 2007

TABLE 2 Data Collected during Habitat Surveys at New Boston Air Force Station

Data Collected
For each transect:
General habitat type description
Dominant plant species in the herbaceous layer (defined as the vertical layer from ground level to 1 m above ground level)
Dominant plant species in the shrub layer (defined as the vertical layer from 1 to 5 m above ground level)
Dominant plant species in the tree layer (defined as the vertical layer greater than 5 m above ground level)
For each quadrat on transects:
General soil type (texture) determined by feel
Percent of the ground layer in each of four categories (bare, rock, log [≥4 cm in diameter], litter)
Percent cover of vegetation in the herbaceous layer in each of four categories (graminoid, forb, woody, total)
Maximum height (cm) of vegetation in the herbaceous layer
Percent cover of all vegetation in the shrub layer
Maximum height (m) of all vegetation in the shrub layer
The presence of a tree canopy above the quadrat

4 RESULTS

4.1 CHARACTERISTICS OF CAPTURED SNAKES

A total of 27 eastern hognose snakes were captured during 2006; 11 of these were adults (10 females, 1 undetermined sex), 14 were juveniles (1 female, 4 males, 9 undetermined sex), and 1 hatchling (undetermined sex). Twenty-two snakes were marked for later recognition with either PIT tags or radiotransmitters. Several juvenile snakes and the hatchling were not marked with PIT tags because there was concern that they were too small for the procedure. Two of these snakes (H001 and H002) had been captured and implanted with radiotransmitters in 2005. In 2007, 11 snakes were captured (8 adults and 3 juveniles); 3 of these (H001, H014, and H015) were captured originally in 2006 but were recaptured in 2007 to replace their transmitters either because the batteries had died or were approaching the end of the typical battery life span (1 year). The characteristics of captured snakes in 2006 and 2007 are presented in Table 3.

Most eastern hognose snakes were captured in areas where they had been observed in previous years, especially in the southwestern portion of the station in the vicinity of the Boresight Tower, along On-Orbit Drive, and in the area that includes the reclaimed borrow pit to the north of Joe English Pond (Figure 7).

4.2 MOVEMENTS OF RADIOTAGGED SNAKES

Eight adult eastern hognose snakes were implanted with radiotransmitters and tracked for varying lengths of time during 2006; nine snakes (including four from 2006) were tracked in 2007 (Table 4; Figures A1–A17 in the Appendix). In both 2006 and 2007, snakes were often difficult to find during July and August. In 2006, the signals for four snakes were last detected in July (H006, H011, and H016) and August (H001) despite intensive searches of the station and an attempt to locate snakes during a helicopter overflight on August 1, 2006. It is presumed that these snakes had burrowed underground, thus reducing the range of the transmitters and making the signals difficult to detect. The variable topography and dense vegetation present within NBAFS may have further obscured the detection of the transmitter signals. The signals of the remaining snakes (H002, H003, H014, and H015) were detected up to November 26, 2006, and these final locations were presumed to be their hibernacula. In 2007, H001, H002, and H030 were tracked until July 26, June 12, and July 17, respectively, when they were found dead. H014, H015, H024, and H026 were tracked into July when their signals were lost. H015 and H026 were detected again in October, presumably at their hibernaculum sites. H025 was tracked throughout the summer until September 16.

Summary statistics on distances moved by radiotagged snakes are shown in Table 5. For snakes with 15 or more locations (H001, H002, H003, H014, and H015 in 2006; H001, H002, H024, H025, and H026 in 2007), the mean distance traveled per day before hibernation ranged from 22 m (H014) to 84 m (H001) in 2006, and 36 m (H025) to 81 m (H026) in 2007. Distance traveled per day varied considerably during the year, as evidenced by the relatively large standard deviations and range of values (0 to 584 m).

TABLE 3 Characteristics of Eastern Hognose Snakes Captured on New Boston Air Force Station in 2006 and 2007

Capture Date	Identi-fication Number[a]	PIT Tag Code	Radio Frequency	Age Class	Sex	Weight (g)	Length (cm)[b]
5/17/06 6/14/07	H001	089-891-540	150.182 148.192[c]	Adult	Female	395 540	-- 74 (SVL)
5/9/06	H002	089-883-820	150.114 150.135[e]	Adult	Female	380	--[d]
5/24/06	H003	--	150.191	Adult	Female	154	59
5/25/06	H004	090-284-278	--	Juvenile	Unknown	9	21
5/25/06	H005	090-030-559	--	Adult	Unknown	740	94
5/28/06	H006	090-285-381	149.073[f]	Adult	Female	483	41
6/5/06	H007	090-285-078	--	Juvenile	Unknown	11.4	22
6/5/06	H008	090-013-267	--	Juvenile	Male	62	46
6/5/06	H009	090-047-796	--	Juvenile	Unknown	12	23
6/6/06	H010	089-894-839	--	Adult	Female	590	90
6/9/06	H011	090-120-885	149.093	Adult	Female	490	83
6/12/06	H012	089-895-636	--	Juvenile	Male	60	24
6/13/06	--	--	--	Juvenile	Unknown	13	20
6/14/06	--	--	--	Juvenile	Unknown	12	20
6/14/06	--	--	--	Juvenile	Unknown	10	20
6/15/06	--	--	--	Juvenile	Unknown	---[g]	--[g]
6/16/06	H013	089-792-120	--	Juvenile	Male	16.5	24
6/20/06 5/4/07	H014	090-046-577	149.052	Adult	Female	470 410	89 78 (SVL)
6/20/06 7/2/07	H015	089-797-124	149.012 148.032	Adult	Female	450 280	85 74 (SVL)
6/22/06	H016	--	149.033	Adult	Female	600	90
6/25/06	H017	090-639-892	--	Juvenile	Unknown	43.0	50
7/25/06	H018	090-827-815	--	Juvenile	Male	32.0	27
8/23/06	H019	089-796-269	--	--	--	--	--
9/9/06	H020	090-614-358	--	Juvenile	Unknown	15	23
9/12/06	H021	090-032-078	--	Juvenile	Female	35	33
9/17/06	--	--	--	Hatchling	Unknown	6	19
9/26/06	H022	090-782-115	--	Adult	Female	161	60
5/24/07	H023	090-030-100	--	Juvenile	--	40	30 (SVL)
6/6/07	H024	089-839-329	150.522	Adult	Female	740	85
6/7/07	H025	090-312-258	150.111	Adult	Female	240	56 (SVL)

Table 3 (Cont.)

Capture Date	Identi-fication Number[a]	PIT Tag Code	Radio Frequency	Age Class	Sex	Weight (g)	Length (cm)[b]
6/23/07	H026	090-258-564	148.172	Adult	Male	300	58 (SVL)
6/23/07	H027	089-850-895	148.151	Adult	Female	660	72 (SVL)
6/30/07	H028	096-362-017	--	Juvenile	Male	80	41 (SVL)
6/29/07	H029	096-354-845	--	Juvenile	Male	53	38
7/8/07	H030	090-849-771	148.012	Adult	Female	410	69 (SVL)

[a] Only snakes that were PIT-tagged or implanted with radiotransmitters were assigned identification numbers.

[b] Length was measured as total body length unless indicated as SVL (snout-vent length).

[c] Snake initially tagged in 2005; implanted with second transmitter on May 18, 2006; implanted with third transmitter on June 14, 2007.

[d] -- = information not applicable or available.

[e] Snake initially tagged in 2005; implanted with second transmitter on August 17, 2006.

[f] Transmitter implanted on June 23, 2006.

[g] Escaped before measurements could be taken.

Figures 8 and 9 present the distance moved by radiotagged eastern hognose snakes according to date in 2006 and 2007. These graphs illustrate a general pattern of periods of relative inactivity (in terms of distance moved per day) with occasional long-distance movements. No obvious pattern is available in terms of the timing of movements although most relatively long-distance movements were made between late May and early August.

Calculated home range size (minimum convex polygon; Powell 2000) of radiotagged snakes varied widely (Table 5). For those snakes with at least 15 locations that were tracked for most of the active period (May through September), four snakes (H001 and H015 in 2006 and H025 and H026 in 2007) had relatively large home ranges (70, 82, 53, and 92 ha, respectively), while the others (H002, H003, and H014 in 2006) had relatively smaller home ranges (12, 21, and 10 ha, respectively).

In the fall of 2006 and spring of 2007, an attempt was made to determine when radiotagged snakes entered and emerged from hibernation, respectively (Table 6). Snakes entered their hibernacula in late September (H002, H003, and H014) or late October (H015). Emergence occurred in late April or early May. Hibernation sites were characterized during habitat surveys conducted in 2007 and are described in Section 4.3.

The recorded behavior of radiotagged snakes when located are shown in Table 7. Most snakes were found resting in the open (53% of observations); less frequently, they were moving, hiding (e.g., under a log or leaf litter), eating, or copulating when observed. Copulation was observed once—H014 was observed copulating with an unknown adult male on September 17, 2006.

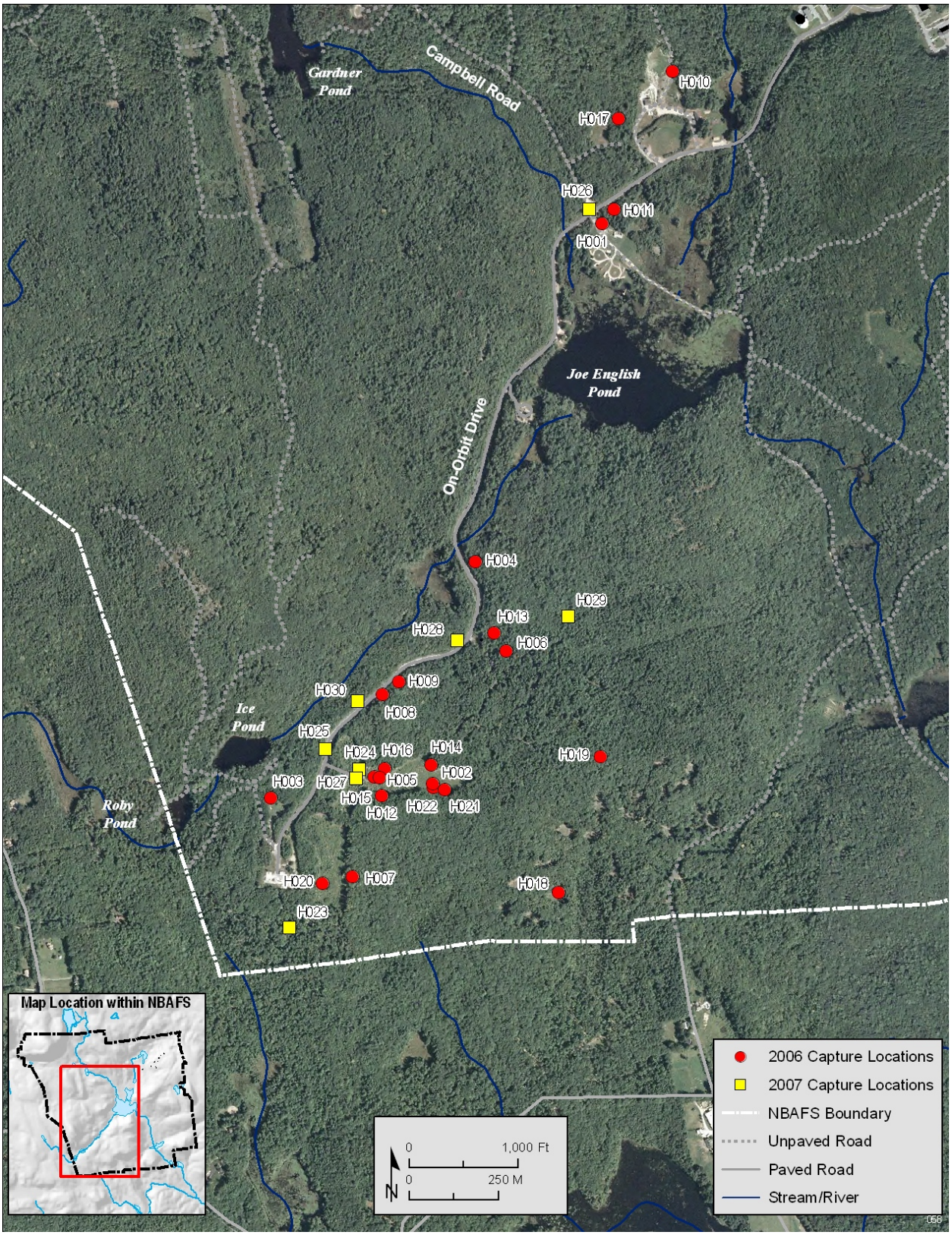


FIGURE 7 Capture Locations of Marked Eastern Hognose Snakes on New Boston Air Force Station in 2006 and 2007

TABLE 4 Tracking Period and Number of Locations Obtained for Radiotagged Eastern Hognose Snakes on New Boston Air Force Station in 2006 and 2007

Identification Number	Age Class	Sex	Tracking Period	Number of Locations
2006				
H001	Adult	Female	5/17/06 to 8/1/06	38
H002	Adult	Female	5/9/06 to 11/26/06	60
H003	Adult	Female	5/24/06 to 11/26/06	50
H006	Adult	Female	5/28/06 to 7/2/06	6
H011	Adult	Female	6/9/06 to 7/2/06	6
H014	Adult	Female	6/20/06 to 11/26/06	32
H015	Adult	Female	6/20/06 to 11/26/06	35
H016	Adult	Female	6/24/06 to 7/2/06	5
2007				
H001	Adult	Female	6/14/06 to 7/26/07	17
H002	Adult	Female	2/2/07 to 6/11/07	21
H014	Adult	Female	2/2/07 to 7/2/07	8
H015	Adult	Female	2/2/07 to 10/21/07	5
H024	Adult	Female	6/6/07 to 7/3/07	15
H025	Adult	Female	6/7/07 to 9/16/07	33
H026	Adult	Male	6/23/07 to 10/22/07	17
H027	Adult	Female	6/23/07 to 6/27/07	2
H030	Adult	Female	7/8/07 to 7/17/07	5

TABLE 5 Distance Moved per Day and Home Range Size of Radiotagged Eastern Hognose Snakes on New Boston Air Force Station in 2006 and 2007

Identi-fication Number	Distance Moved Per Day (m)[a]					Home Range[b]	
	N	Mean	SD	Maximum	Minimum	N	Area (ha)
2006							
H001	35	84	147	584	0	38	**70.2**
H002	45	37	53	226	0	60	**12.0**
H003	39	31	57	296	0	50	**20.9**
H006	4	8	4	11	3	6	0.3
H011	4	61	39	96	4	6	2.3
H014	21	22	23	74	1	32	**9.8**
H015	26	43	63	219	0	35	**81.7**
H016	4	7	8	18	2	5	0.03
2007							
H001	15	69	121	480	1	17	43.6
H002	16	56	100	381	3	21	9.9
H014	4	58	77	171	0	8	22.2
H015	1	232	--	232	232	5	26.3
H024	14	61	88	298	0	15	7.2
H025	29	36	49	219	0	33	**52.8**
H026	15	81	108	356	2	17	**91.6**
H027	1	14	--	14	14	2	--
H030	2	14	19	27	0	5	0.6

[a] Distance moved per day was calculated for the period prior to hibernation and only for consecutive observations where the number of days between observations was 5 days or less. N is the number of locations used in the calculations.

[b] Home range was calculated as the minimum convex polygon that included all locations. N is the number of locations used in the calculations. Home range values in bold text were based on tracking data over most of the active period (May through September), and were, therefore, considered most representative of the annual home range.

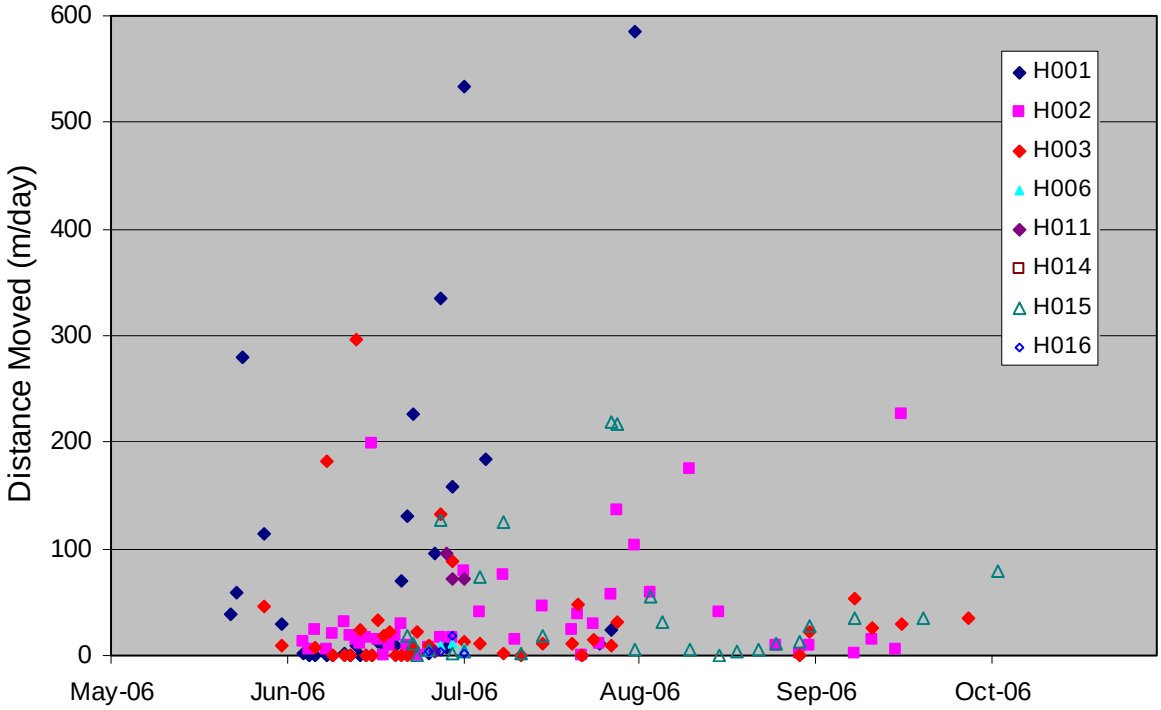


FIGURE 8 Distances Moved by Radiotagged Eastern Hognose Snakes according to Date on New Boston Air Force Station in 2006

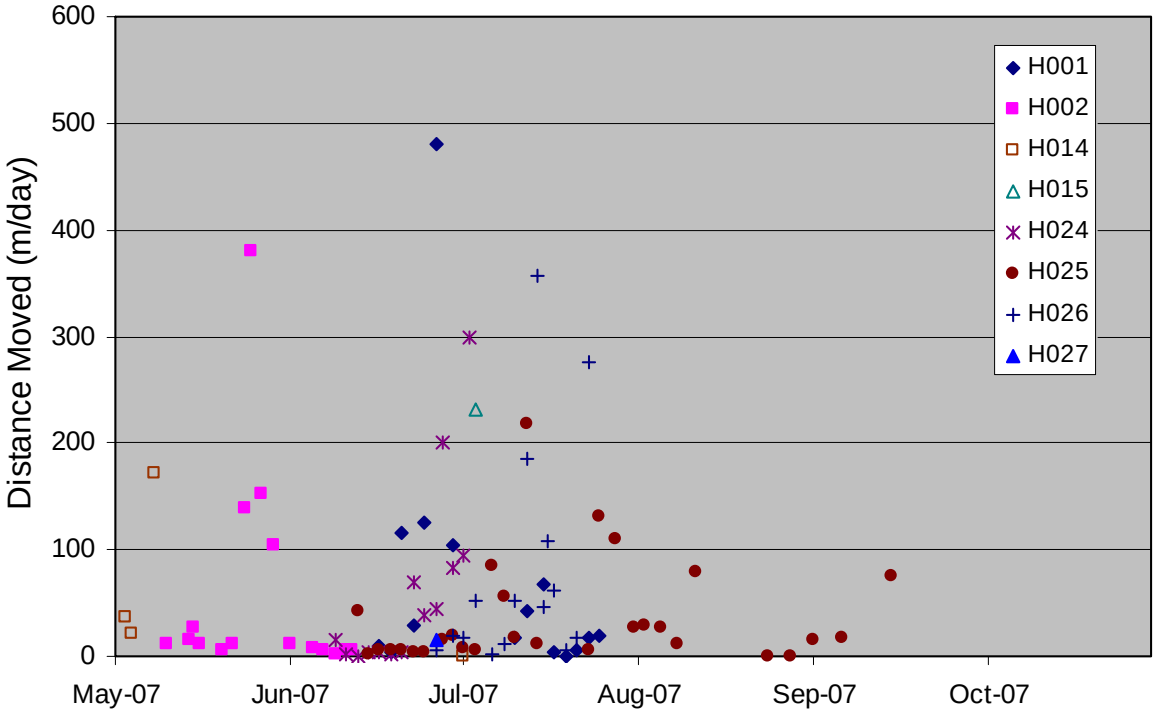


FIGURE 9 Distances Moved by Radiotagged Eastern Hognose Snakes according to Date on New Boston Air Force Station in 2007

TABLE 6 Estimated Dates That Radiotagged Eastern Hognose Snakes Entered and Emerged from Hibernation on New Boston Air Force Station

Identification Number	Date Entered Hibernation	Date Emerged from Hibernation
H002	Between 9/17 and 9/29/06	Between 5/8 and 5/10/07
H003	Between 9/26 and 9/29/06	--[a]
H014	Between 9/26 and 9/29/06	Between 4/22 and 4/29/07
H015	Between 10/27 and 11/4/061	Between 4/22 and 7/2/07

[a] Snake apparently died in hibernaculum.

TABLE 7 Observed Behaviors of Radiotagged Eastern Hognose Snakes on New Boston Air Force Station in 2006 and 2007

Behavior[a]	Frequency	Percent of Observations
Resting in open	101	53
Moving	49	26
Hiding	40	21
Eating	1	1
Copulating	1	1
Total	116	100

[a] Behavior was recorded by the observer at the time of location.

4.3 DISTRIBUTION AND HABITAT USE

Figures 10 and 11 present maps of all hognose snake capture and telemetry locations during 2006 and 2007, respectively. Most snake locations were in the southwestern portion of the station near the Boresight Tower, along On-Orbit Drive, and in the area that includes the reclaimed borrow pit to the north of Joe English Pond.

Although some of the observed distribution pattern may be an artifact of the relative ease with which some areas can be searched for new snakes and the positive feedback that occurred when snakes were found, the movement patterns of radiotagged snakes can be used to determine if snakes use habitat elsewhere on the station. Telemetry indicated that snakes also use the area

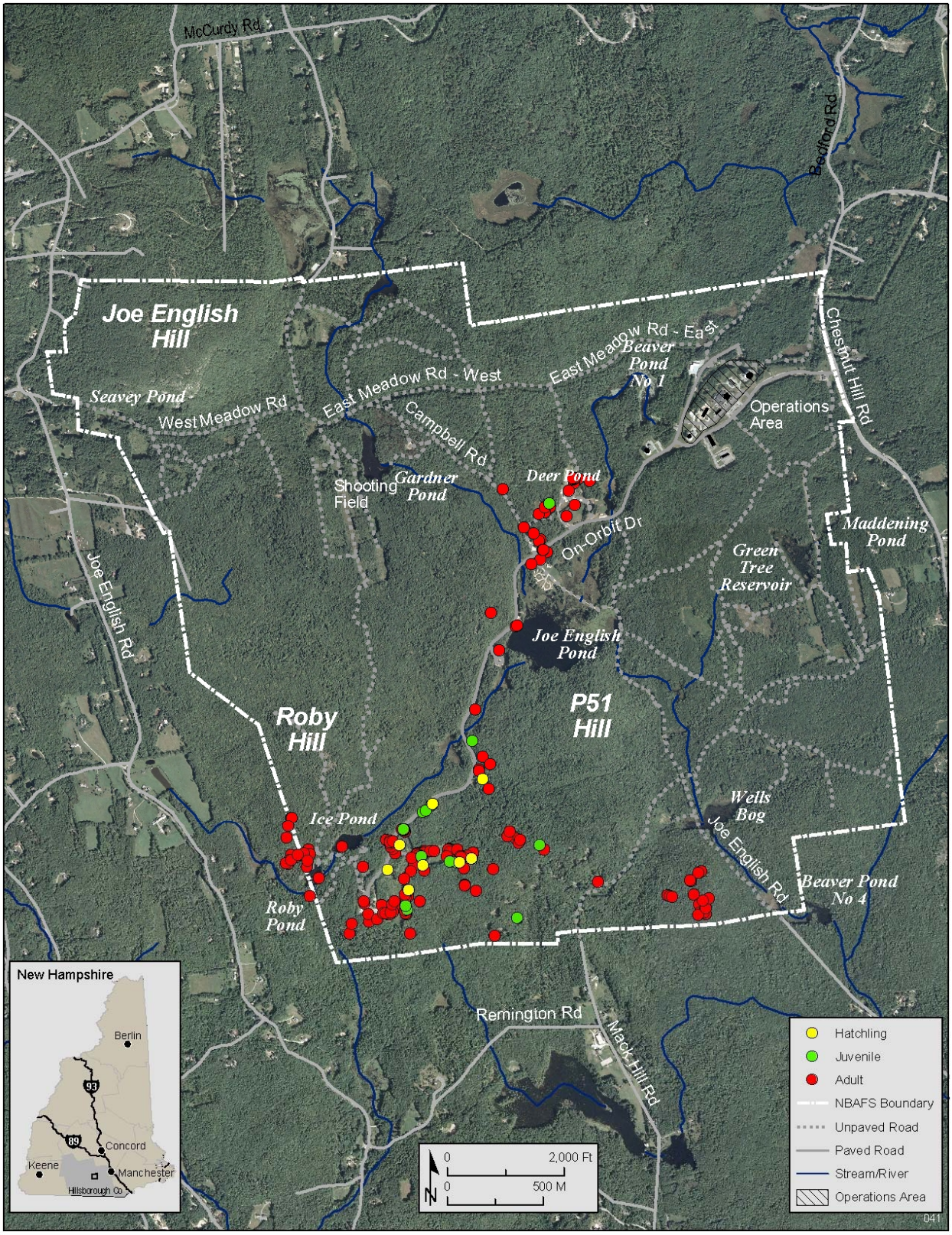


FIGURE 10 Map of All Observed Locations of Eastern Hognose Snakes on New Boston Air Force Station during 2006

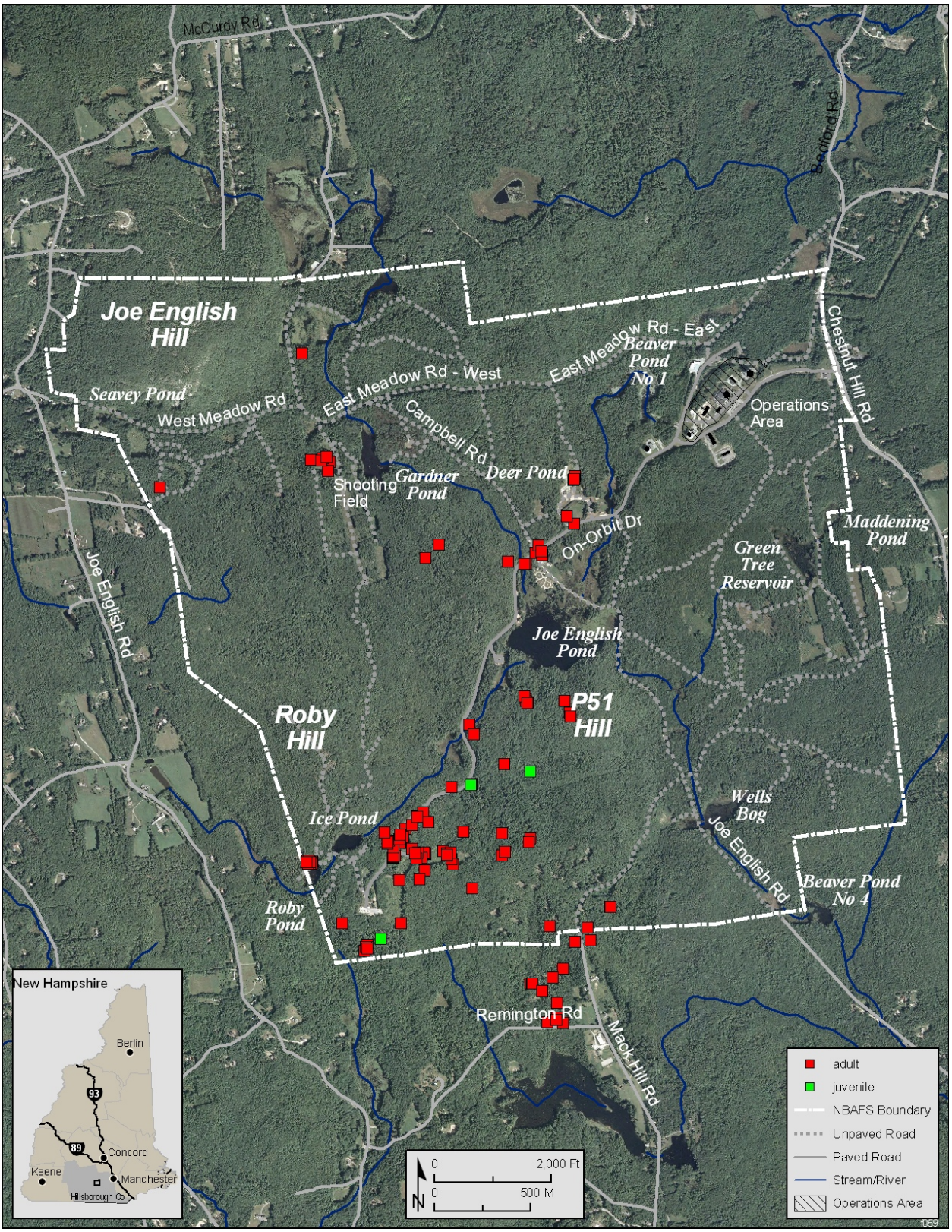


FIGURE 11 Map of All Observed Locations of Eastern Hognose Snakes on New Boston Air Force Station during 2007

between Roby Hill and Roby Pond (H003, Figure A3), the area south and southwest of P51 Hill (H014, Figure A11; H015, Figures A7 and A12; and H025, Figure A14), the Shooting Field and areas in the northwestern portion of the station (H026, Figure A15), and even make movements off the station (H025, Figure A14). Concern over the bias toward certain capture locations prompted increased searching in more offroad portions of the station in 2007.

Habitats in which radiotagged eastern hognose snakes were observed included mixed forest, dense oldfield, open oldfield, forest edge, road edge, and forest harvest areas (Figure 12). Most locations were characterized as mixed forest or dense oldfield (Table 8).

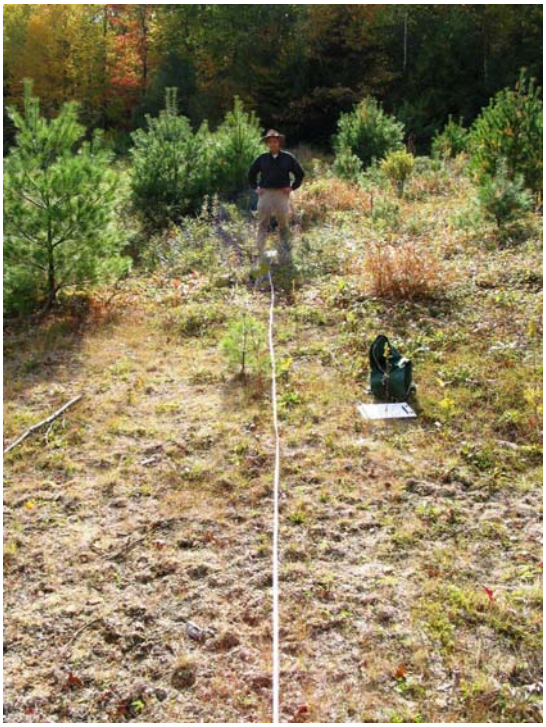
Habitat characteristics as determined from detailed habitat surveys conducted at known radiotagged snake locations and randomly chosen points are presented in Table 9. Data from 2006 and 2007 were pooled for this analysis. For most variables, there were no statistically significant differences between the mean at non-hibernation snake locations and random points, but snake locations had a significantly higher percent of bare ground (6.7% vs. 0.9%) and significantly lower percent cover of logs (3.6% vs. 6.9%). The only detected significant difference between habitat characteristics at hibernation locations and random locations was a lower percent total cover in the herbaceous layer at hibernation sites (7.5% vs. 19.5%).

Dominant plant species in the herbaceous, shrub, and tree layer at radiotagged snake locations and randomly chosen points are presented in Table 10. No statistically significant differences in dominant plant species occurrence at snake locations and random locations were detected.

The soils at most known snake locations were sandy (94% of locations were characterized as having sandy loam, loamy sand, gravelly sand, or sand soils), whereas only 64% of random points had sandy soils. Soils at three of the hibernation sites were characterized as sandy loam soil; the soil at one site was characterized as silt loam.

Mixed woodland

Forest edge



Open oldfield

Dense oldfield

FIGURE 12 Habitat Types at Radiotagged Eastern Hognose Snake Locations on New Boston Air Force Station

Road edge

Forest harvest area

FIGURE 12 (Cont.)

TABLE 8 Habitat Types at Radiotagged Eastern Hognose Snake Locations on New Boston Air Force Station in 2006 and 2007

Habitat Type[a]	Number of Locations in Habitat	% of Total Locations
Mixed forest	84	30
Dense oldfield	66	24
Forest edge	43	15
Open oldfield	33	12
Road edge	32	11
Forest harvest area	21	8
Total	279	100

[a] Habitat type was recorded by the observer at the time of location.

TABLE 9 Summary Habitat Statistics for Transects at Radiotagged Snake Locations and Random Points on New Boston Air Force Station in 2006 and 2007

	Snake Locations Non-hibernation (N = 28)		Snake Locations Hibernation Sites (N = 4)		Random Points (N = 18)		Non-hiber-nation vs. Random	Hiber-nation vs. Random
Variable	Mean	SD	Mean	SD	Mean	SD	$P > t$[a]	$P > t$[a]
Percent Cover in Ground Layer								
Bare	6.7	14.4	0.9	1.4	0.9	1.6	**0.04**[b]	0.99
Rock	5.3	8.5	3.3	5.8	6.3	9.2	0.71	0.54
Log	3.6	4.1	2.0	2.1	6.9	5.8	**0.03**	0.12
Litter	81.4	23.0	92.8	5.2	84.3	9.5	0.55[b]	0.10
Percent Cover in Herbaceous Layer								
Graminoid	4.0	7.6	0.7	0.9	1.2	3.5	0.15[b]	0.54
Forb	12.1	14.9	2.2	4.3	6.1	10.9	0.15	0.50
Woody	20.8	23.4	4.7	4.6	11.8	13.0	0.12[b]	0.30
Total	33.0	27.9	7.5	3.7	19.5	18.2	0.15	**0.02**
Maximum height of vegetation in herbaceous layer (cm)	48.0	28.3	27.9	14.0	34.9	26.7	0.12	0.62
Percent cover in shrub layer	28.3	22.4	34.1	12.7	19.7	17.7	0.17	0.14
Maximum height of vegetation in shrub layer (m)	2.6	1.4	3.6	0.8	2.5	1.6	0.82	0.22
Percent of quadrats with tree canopy	26.7	39.1	15.8	29.5	39.4	46.3	0.32	0.34

[a] *P*-values less than or equal to 0.05 are considered statistically significant using a two-tailed *t*-test (SAS version 9.1 for Windows) and are indicated in bold text.

[b] Based on *t*-test for populations with unequal variances; all others based on *t*-test for populations with equal variances.

TABLE 10 Dominant Plant Species on Transects at Non-Hibernation Snake Locations and Random Points on New Boston Air Force Station

		Percent of Transects with Species Present[a]					
		Herbaceous Layer		Shrub Layer		Tree Layer	
Common Name	Scientific name	Snake Locations	Random Points	Snake Locations	Random Points	Snake Locations	Random Points
American beech	*Fagus grandifolia*	25	17	43	28	14	22
American chestnut	*Castanea dentata*	0	0	4	0	0	0
Northern shorthusk	*Brachyelytrum aristosum*	0	6	0	0	0	0
Black birch	*Betula lenta*	4	0	0	0	7	6
Bracken fern	*Pteridium aquilinum*	14	6	0	0	0	0
Broomsedge	*Andropogon scoparius*	7	0	0	0	0	0
Cinnamon fern	*Osmunda cinnamomea*	7	11	0	0	0	0
Club moss	*Lycopodium* spp.	7	11	0	0	0	0
Common juniper	*Juniperus communis*	4	0	0	0	0	0
Dewberry	*Rubus hispidus*	11	0	0	0	0	0
Eastern hemlock	*Tsuga canadensis*	25	28	43	28	29	28
Eastern white pine	*Pinus strobus*	14	11	21	33	21	17
English plantain	*Plantago lanceolata*	4	0	0	0	0	0
Fireweed	*Erechtites hieracifolia*	7	0	4	0	0	0
Goldenrod	*Solidago* spp.	14	0	0	0	0	0
Gray birch	*Betula populifolia*	4	0	14	0	14	11
Green ash	*Fraxinus pennsylvanica*	0	0	0	6	0	0
Hay-scented fern	*Dennstaedtia punctilobula*	4	11	0	0	0	0
Heal-all	*Prunella* sp.	4	0	0	0	0	0
Hobblebush	*Viburnum alnifolium*	0	6	0	0	0	0
Indian cucumber root	*Medeola virginiana*	4	6	0	0	0	0
Lady fern	*Athyrium filix-femina*	4	0	0	0	0	0

Table 10 (Cont.)

		Percent of Transects with Species Present[a]					
		Herbaceous Layer		Shrub Layer		Tree Layer	
Common Name	Scientific name	Snake Locations	Random Points	Snake Locations	Random Points	Snake Locations	Random Points
Lowbush blueberry	*Vaccinium angustifolium*	32	11	0	0	0	0
Marsh fern	*Thelypteris palustris*	0	6	0	0	0	0
Massachusetts fern	*Thelypteris simulata*	14	0	0	0	0	0
Mountain laurel	*Kalmia latifolia*	0	11	0	11	0	0
New York fern	*Thelypteris novaboracensis*	7	0	0	0	0	0
Panic grass	*Panicum* sp.	4	0	0	0	0	0
Partridgeberry	*Mitchella repens*	4	0	0	0	0	0
Poison ivy	*Toxicodendron radicans*	0	6	0	0	0	0
Queen Anne's lace	*Daucus carota*	4	0	0	0	0	0
Paper birch	*Betula papyrifera*	0	0	4	0	4	0
Red maple	*Acer rubrum*	4	0	18	6	43	56
Red oak	*Quercus rubra*	11	0	11	11	21	67
Rhododendron	*Rhododendron* sp.	0	11	0	6	0	0
Rubus	*Rubus* sp.	25	0	4	0	0	0
Wild sarsaparilla	*Aralia nudicaulis*	11	0	0	0	0	0
Sedge	--	21	11	0	0	0	0
Sphagnum	*Sphagnum magellanicum*	21	0	0	0	0	0
Spirea	*Spirea* spp.	7	0	4	0	0	0
Starflower	*Trientalis borealis*	4	0	0	0	0	0
Striped maple	*Acer pensylvanicum*	4	0	4	0	0	0
Sugar maple	*Acer saccharum*	0	0	4	6	0	6
Sweet fern	*Comptonia peregrina*	18	6	4	6	0	0
Trailing arbutus	*Epigaea repens*	4	0	0	0	0	0
Unidentified fern	--	11	0	0	0	0	0
Unidentified grass	--	11	6	0	0	0	0

Table 10 (Cont.)

		Percent of Transects with Species Present[a]					
		Herbaceous Layer		Shrub Layer		Tree Layer	
Common Name	Scientific name	Snake Locations	Random Points	Snake Locations	Random Points	Snake Locations	Random Points
Unidentified moss	--	0	6	0	0	0	0
White ash	*Fraxinus americana*	0	6	0	0	4	0
White oak	*Quercus alba*	0	0	0	0	0	0
Wild strawberry	*Fragaria virginiana*	4	0	0	0	0	0
Wintergreen	*Gaultheria procumbens*	18	28	0	0	0	0
Witch hazel	*Hamamelis virginiana*	11	6	29	28	0	0
Yellow birch	*Betula alleghaniensis*	0	6	25	0	7	28
No plants	--	0	6	7	11	29	6

[a] No differences in plant species occurrence were detected between snake locations and random locations using χ^2 tests of independence. $P > \chi^2 = 0.28$, 0.65, and 0.82, for the herbaceous, shrub, and tree layers, respectively (SAS version 9.1 for Windows).

5 DISCUSSION

The eastern hognose snake appears to be well established on NBAFS. Eastern hognose snakes have been regularly encountered on NBAFS since the late 1990s. Individuals captured during the study represented a full range of age and weights, indicating a healthy reproducing population. Although no adult males were captured in 2006 and only one in 2007 (H026), this may not represent a skewed sex ratio, but may rather be indicative of behavioral or distributional differences between the sexes that made the capture of males less likely than females. Indeed, this individual had the largest home range of any radiotagged hognose snake in our study, which included a portion of the station where other hognose snakes were not observed. Insufficient data are available to derive a population estimate based on the recapture of marked individuals, but such an estimate may be possible in the future, however, if PIT-tagging of snakes and annual surveys are conducted.

Areas on NBAFS that seem to be favored by eastern hognose snakes include the area near the Boresight Tower to the southwest, along On-Orbit Drive in the central portion of the station, and areas to the north of Joe English Pond. Telemetry data demonstrated that other portions of the station also are used, if less frequently. Although it is possible that the apparent distribution pattern is a result of snakes being more easily detected and captured in those locations, intensive searches in other areas and monitoring of movement patterns of radiotagged snakes did not greatly expand the known distribution of snakes on the station.

Movement patterns observed on NBAFS are consistent with other researchers who have documented periods of inactivity, especially during hotter times of the year, with episodic long distance movements (Plummer and Mills 2000; Brookhaven National Laboratory 2007). For at least one snake (H001), several movements were along On-Orbit Drive which may represent a relatively easily traversed path through otherwise hilly terrain. If this road serves as an important travel corridor on NBAFS, the risk of mortality from vehicles may be accentuated. Enge and Wood (2002, 2003) frequently observed southern hognose snakes (*Heterodon simus*) along roadways and surmised that vehicle collisions could be a significant source of mortality (estimated at 2.3 km of road/yr) especially of dispersing hatchlings.

The home range sizes of most eastern hognose snakes on NBAFS were fairly comparable to those found by Plummer and Mills (2000) in Arkansas (mean of 50 ha in Arkansas), although home range size on NBAFS was quite variable. The only male tracked in our study (H026) had the largest home range of any other radiotagged snake on NABFS (92 ha) and was the only hognose snake ever observed in the northwestern portion of the station. As reported by Plummer and Mills (2000) for hognose snakes in Arkansas, the location of individual home ranges on NBAFS seemed consistent between the two years of our study, suggesting strong philopatry.

A wide variety of habitats (including mature mixed forest, early successional habitats, and forest harvest area) were used by eastern hognose snakes on NBAFS, and our study did not detect any preference for a particular habitat characteristic as evidenced by a lack of significant differences between snake locations and random locations for most habitat variables. Habitats used by eastern hognose snakes on NBAFS are consistent with observations on Long Island (Brookhaven National Laboratory 2007), which demonstrated use of scrubland, grassland,

firebreaks, and disturbed areas, and in Arkansas where Plummer and Mills (2000) found hognose snakes to use a variety of open and edge habitats. Our observations are not consistent with Michener and Lazell's (1989) description of the southern New Hampshire population of eastern hognose snake as occupying "inland sandy habitats dominated by white pine," although a preference for sandy soils was apparent in our data.

Management practices that maintain a diversity of habitats on NBAFS, including early successional habitats, should favor the eastern hognose snake population on the station. Timber harvest and prescribed fire are important tools that have been and can continue to be used to maintain habitat diversity. Because of its fossorial habit, the species is potentially sensitive to any activity that would cause ground disturbance such as compaction or excavation when individuals are most likely to be underground (late September through April). The impacts of any such activities on this species should be reviewed prior to implementation. In the future, particular attention should be focused on evaluating the impacts of any activities planned or proposed in the southwestern portion of NBAFS, which appears to be a preferred area of the species, and traffic mortality along On-Orbit Drive.

During our study, several radiotagged snakes were found dead or their transmitters were recovered with no sign of the snake's remains. When H003 did not emerge from hibernation in the spring of 2007, the hibernation site was excavated (on June 13, 2007) and the snake's decaying carcass (with functioning transmitter) was found within a foot of the ground surface. It was not clear if the snake died during hibernation (because it was at an insufficient depth to prevent freezing) or if it had died while emerging. H001's carcass was found on July 26, 2007. When last observed, the snake appeared thin and had moved little over the preceding week. H002's transmitter was found on June 12, 2007 (last visual observation on June 1); no sign of the snake's remains was found and it was presumed to have been eaten by a predator. Similarly, H030's transmitter was found on July 17, 2007, shortly after the snake was released following implantation of its transmitter on July 9. Given the short time between implantation and recovery of the transmitter, it is possible that H030 did not die, but that the transmitter was expelled through the fresh incision.

This information suggests the possibility that our study methods placed radiotagged snakes at increased risk of mortality. Implantations could have impaired the health of individuals through infection at the transmitter implantation site or by affecting their ability to move or capture prey. Observed condition of H001 prior to death indicated poor health although she had made a number of fairly long-distance moves in the weeks preceding death. H003's death could be explained if the transmitter (which can result in a slight external bulge) prevented the snake from burrowing deeply enough for hibernation or inhibited the snake's emergence from the hibernaculum. Handling of snakes and repeated attempts to establish visual contact with radiotagged snakes during the study may have attracted predators (e.g., raccoons [*Procyon lotor*] or striped skunks [*Mephitis mephitis*]) to the snakes. Given the potential for an adverse effect of our study methods on the eastern hognose snake population on NBAFS, we recommend a cautious approach and full review of procedures if similar studies are planned for the future.

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APPENDIX:

MAPS OF RADIOTAGGED EASTERN HOGNOSE SNAKE LOCATIONS ON NEW BOSTON AIR FORCE STATION IN 2006 AND 2007

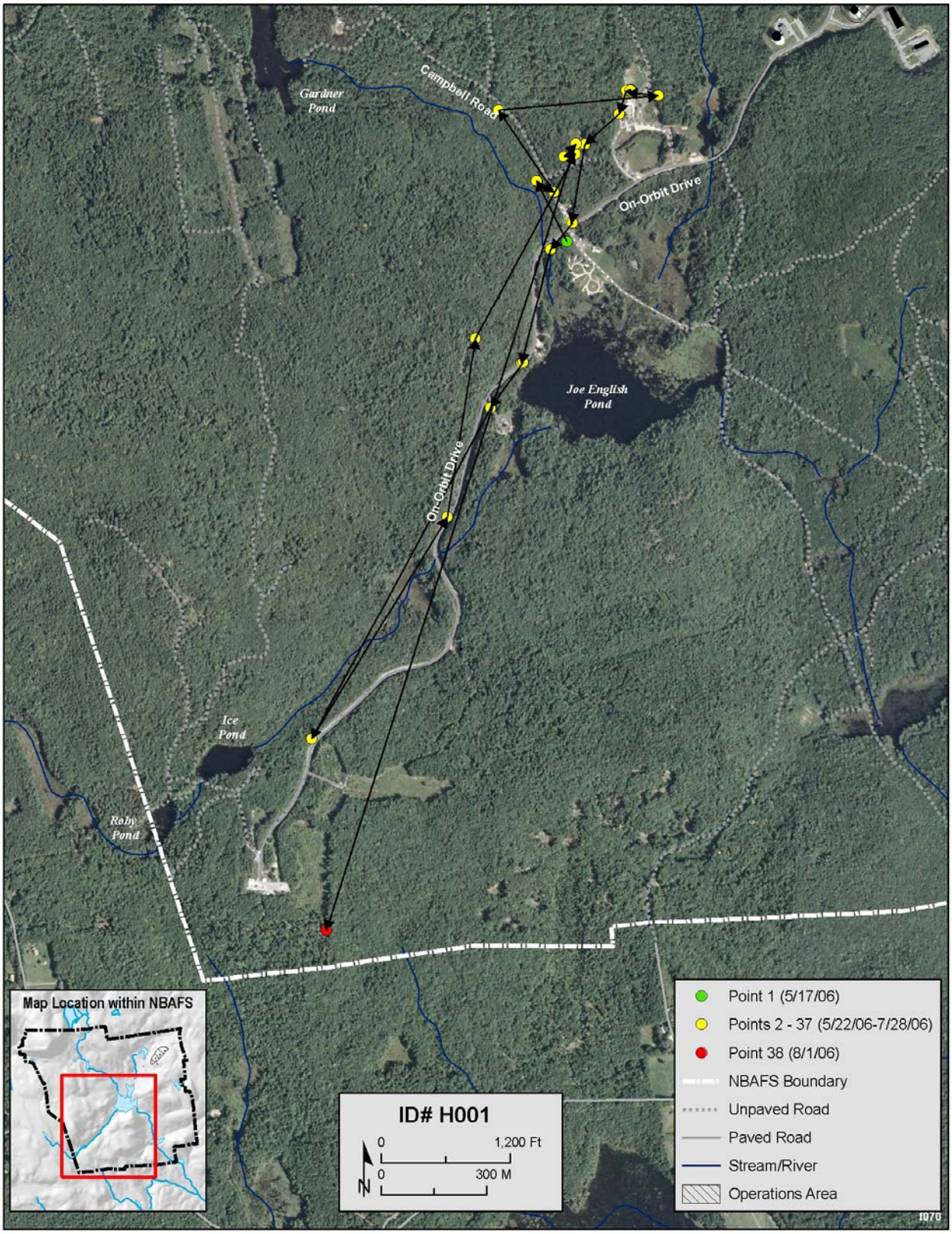

FIGURE A1 Movements of Adult Female H001 on New Boston Air Force Station in 2006

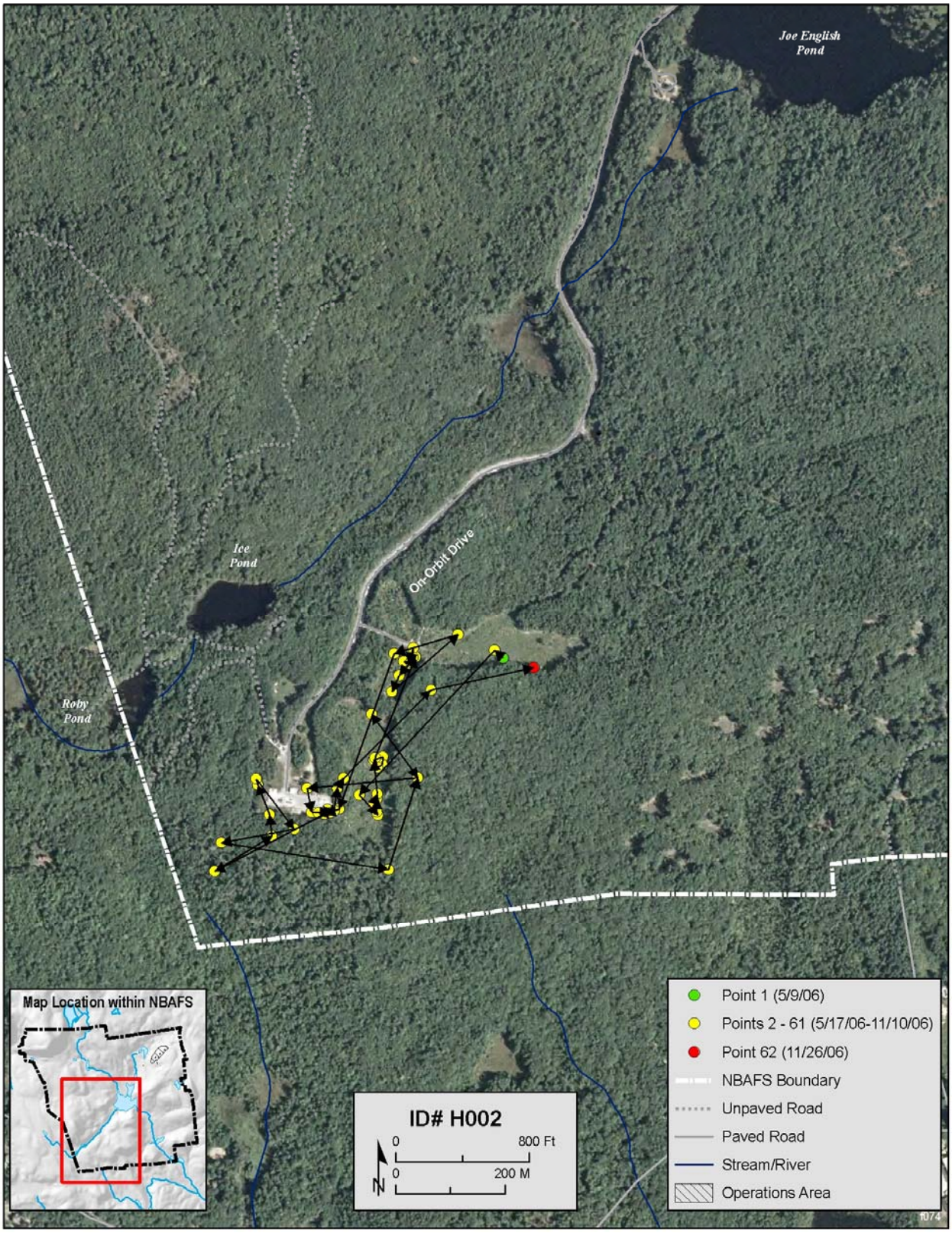

FIGURE A2 Movements of Adult Female H002 on New Boston Air Force Station in 2006

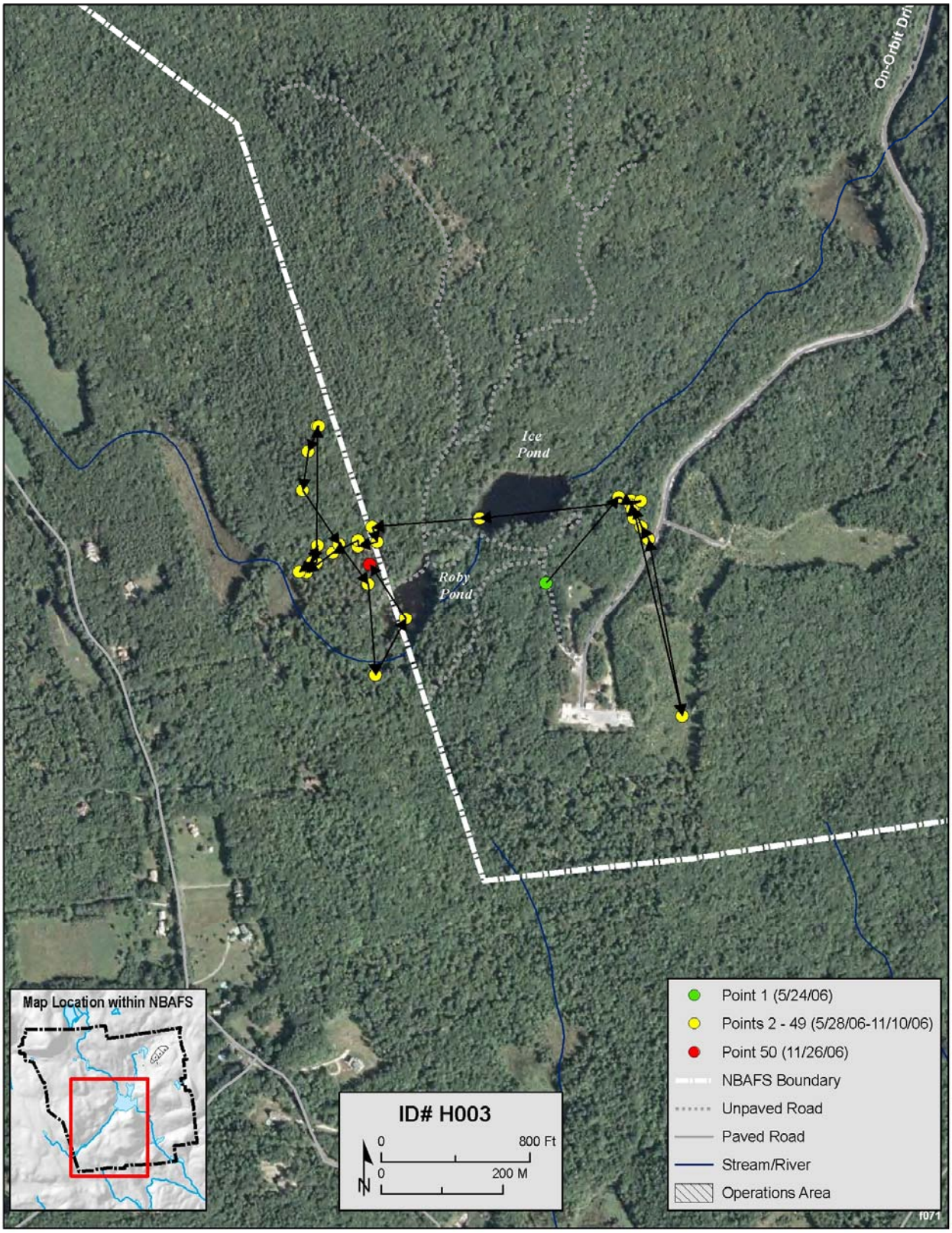

FIGURE A3 Movements of Adult Female H003 on New Boston Air Force Station in 2006

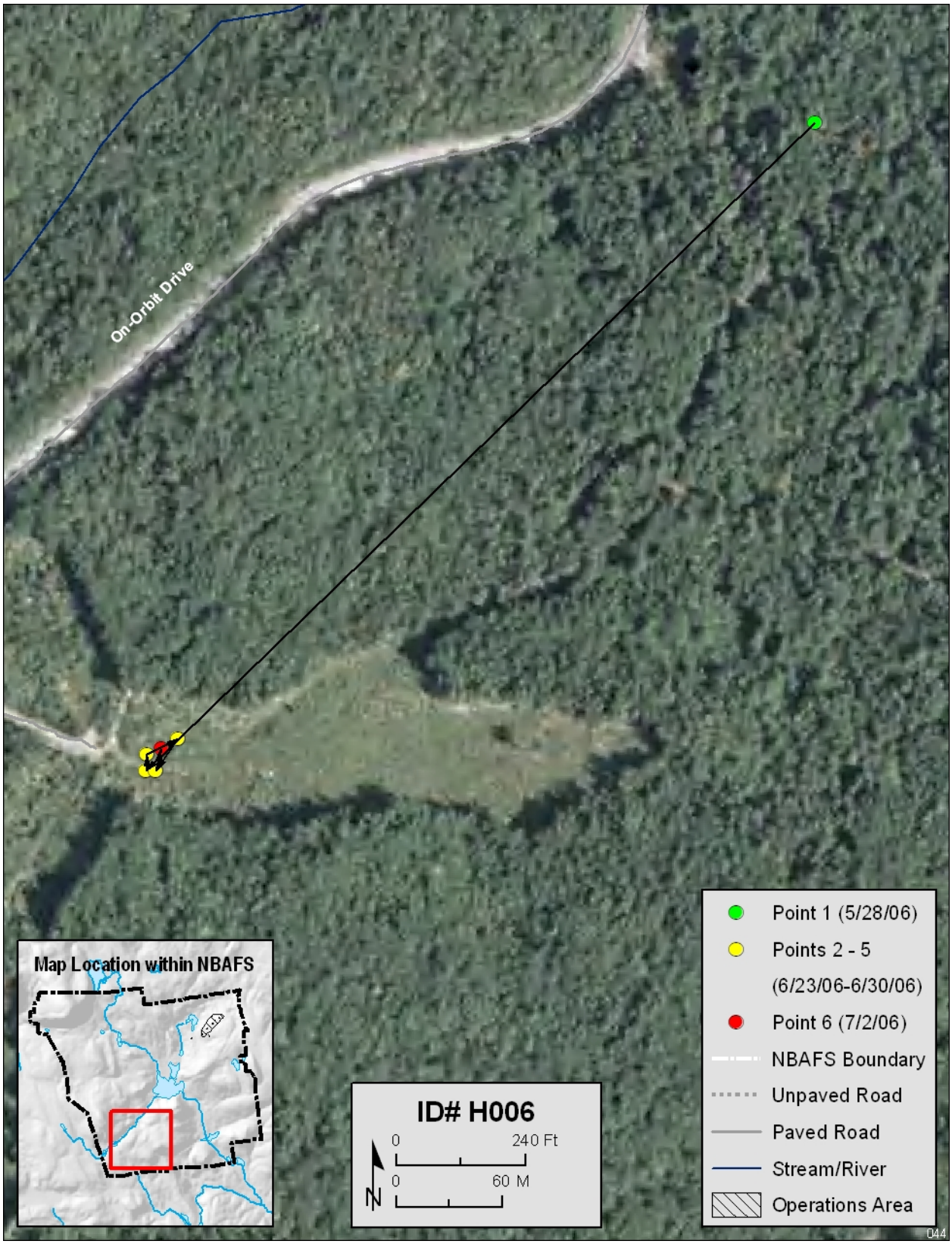

FIGURE A4 Movements of Adult Female H006 on New Boston Air Force Station in 2006

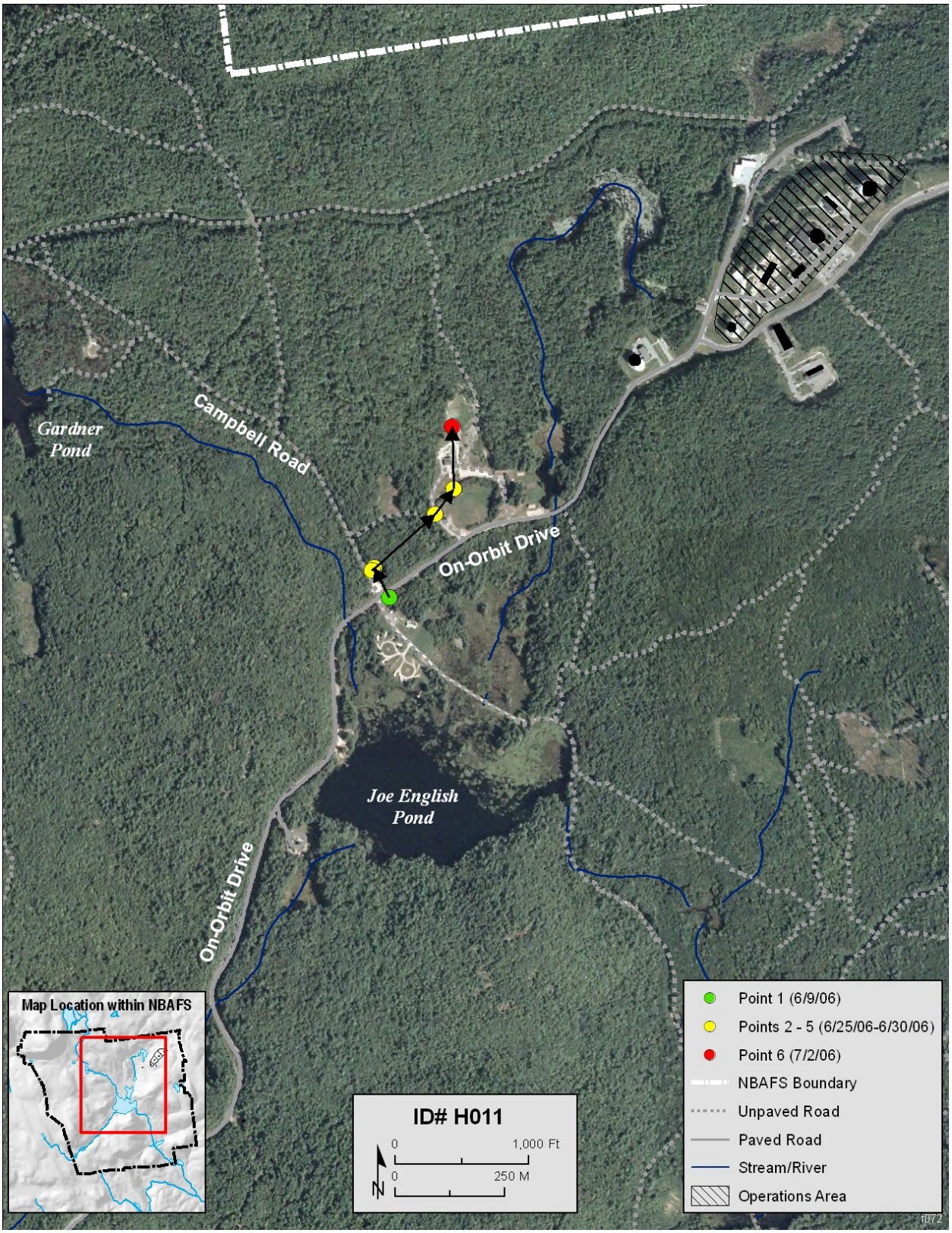

FIGURE A5 Movements of Adult Female H011 on New Boston Air Force Station in 2006

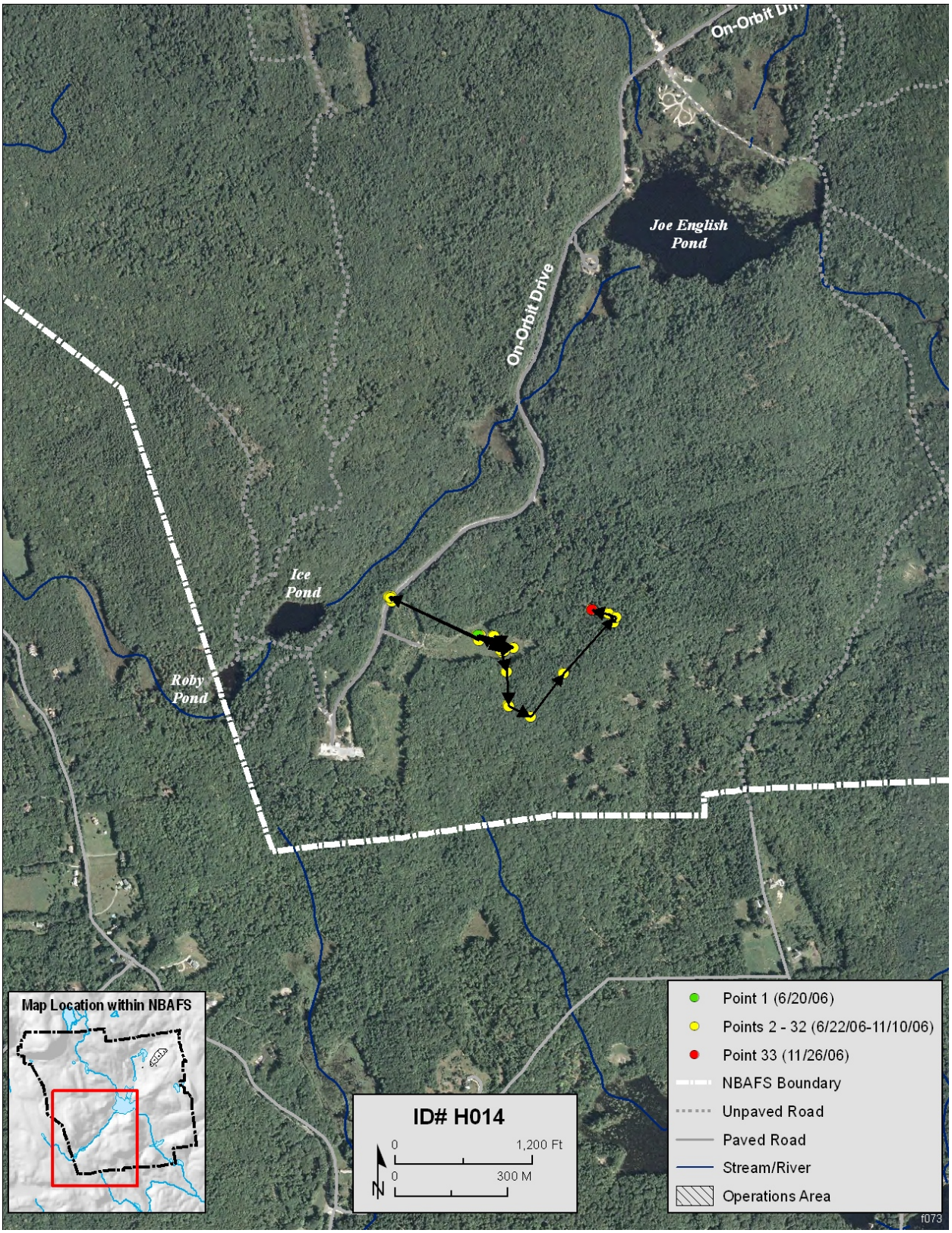

FIGURE A6 Movements of Adult Female H014 on New Boston Air Force Station in 2006

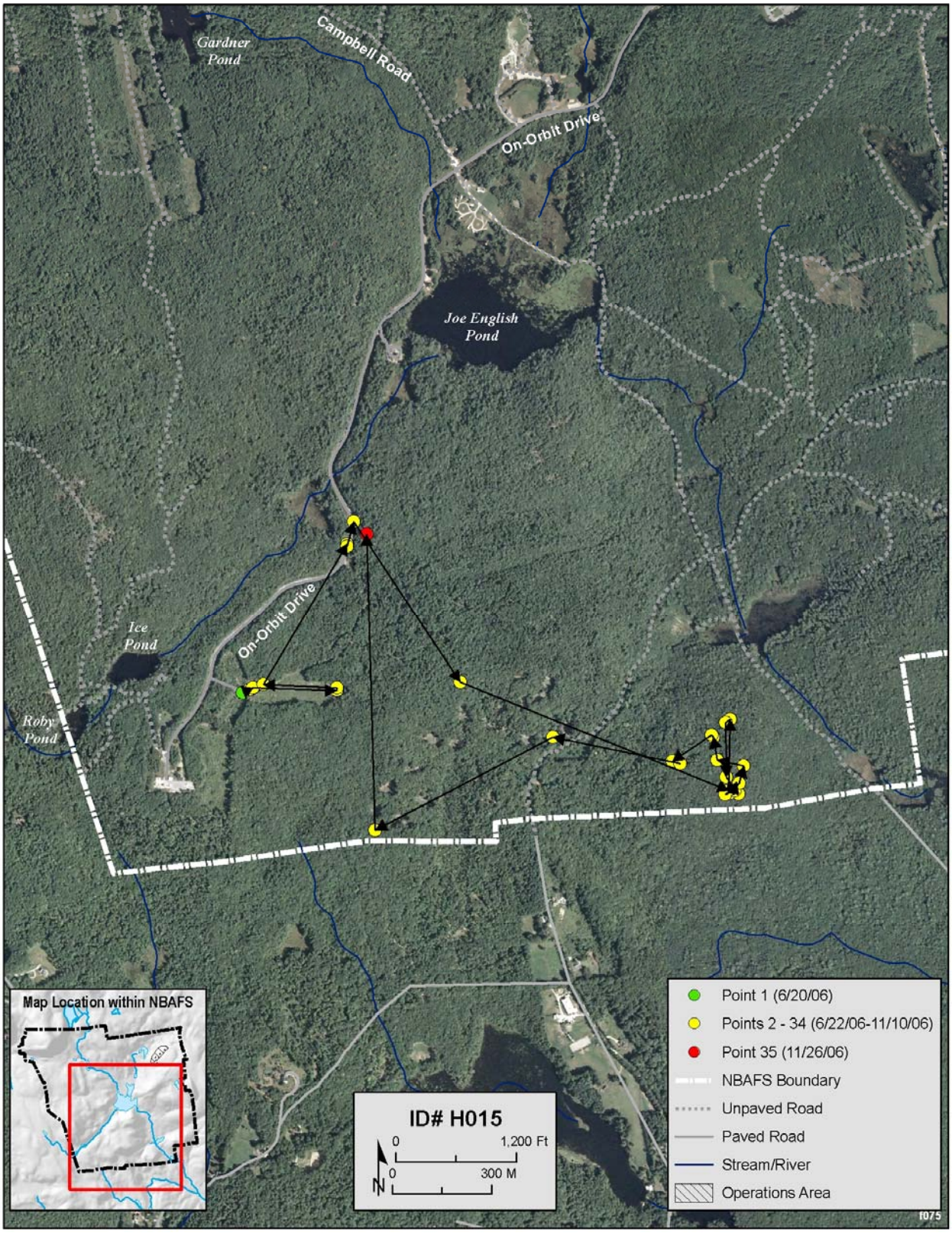

FIGURE A7 Movements of Adult Female H015 on New Boston Air Force Station in 2006

FIGURE A8 Movements of Adult Female H016 on New Boston Air Force Station in 2006

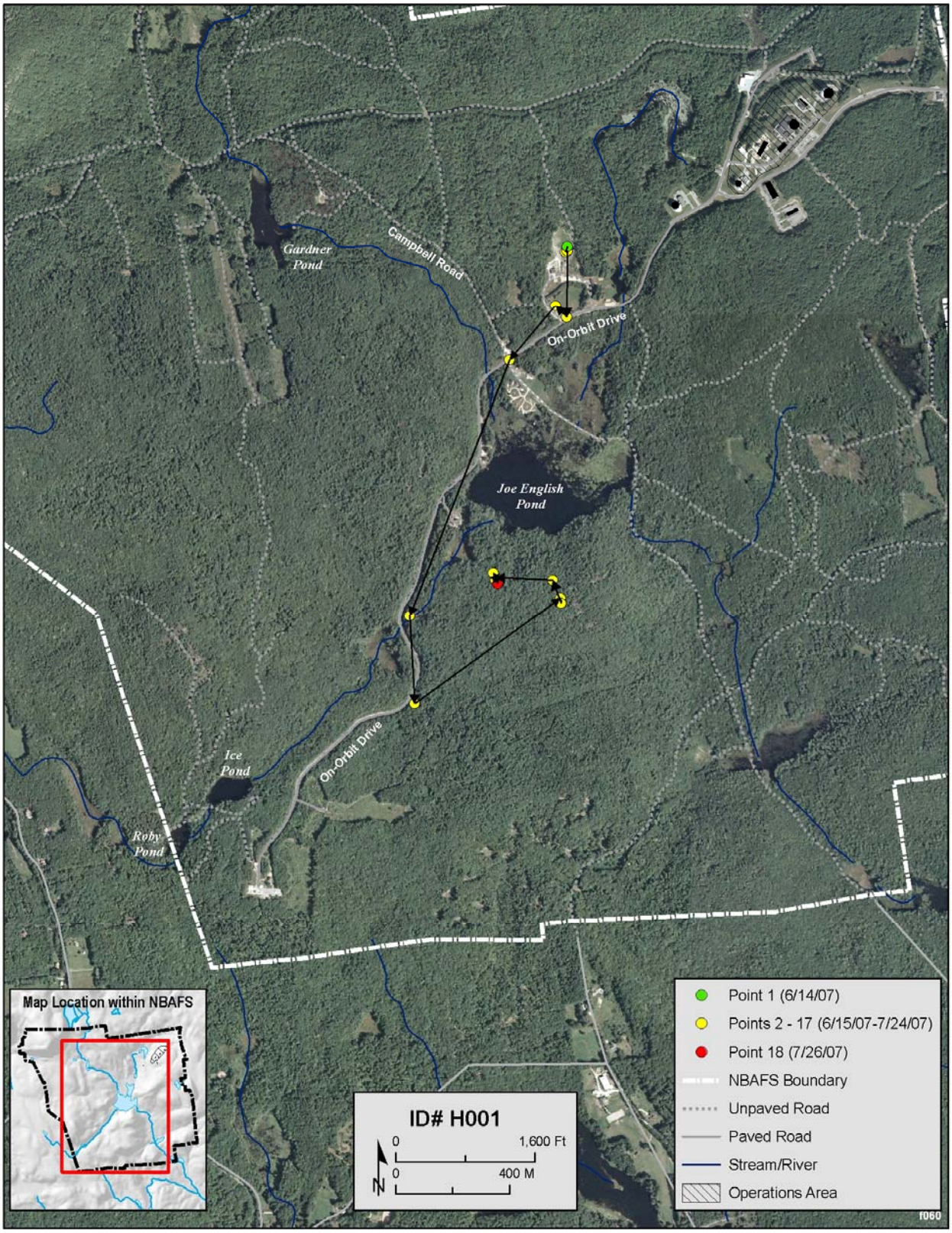

FIGURE A9 Movements of Adult Female H001 on New Boston Air Force Station in 2007

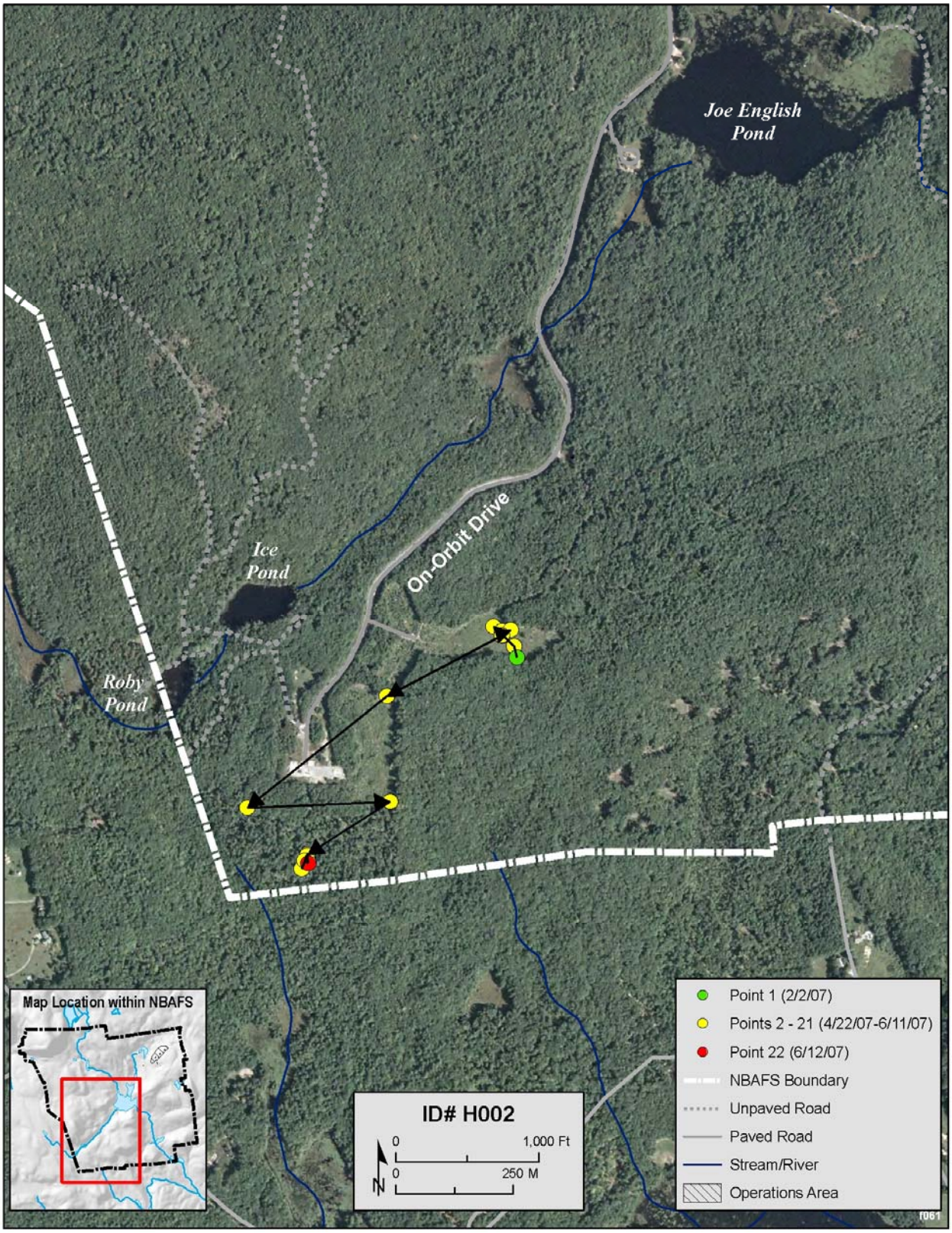

FIGURE A10 Movements of Adult Female H002 on New Boston Air Force Station in 2007

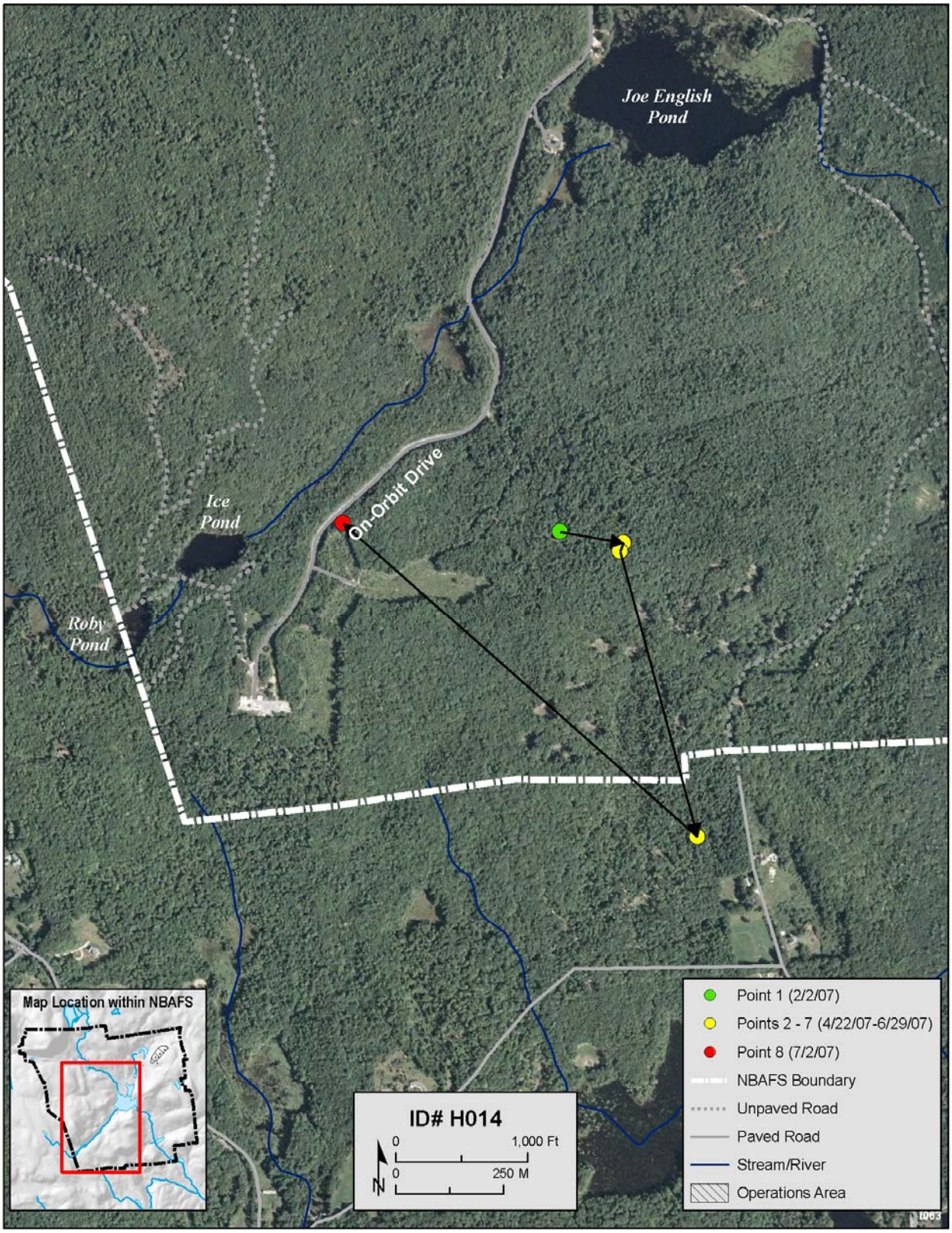

FIGURE A11 Movements of Adult Female H014 on New Boston Air Force Station in 2007

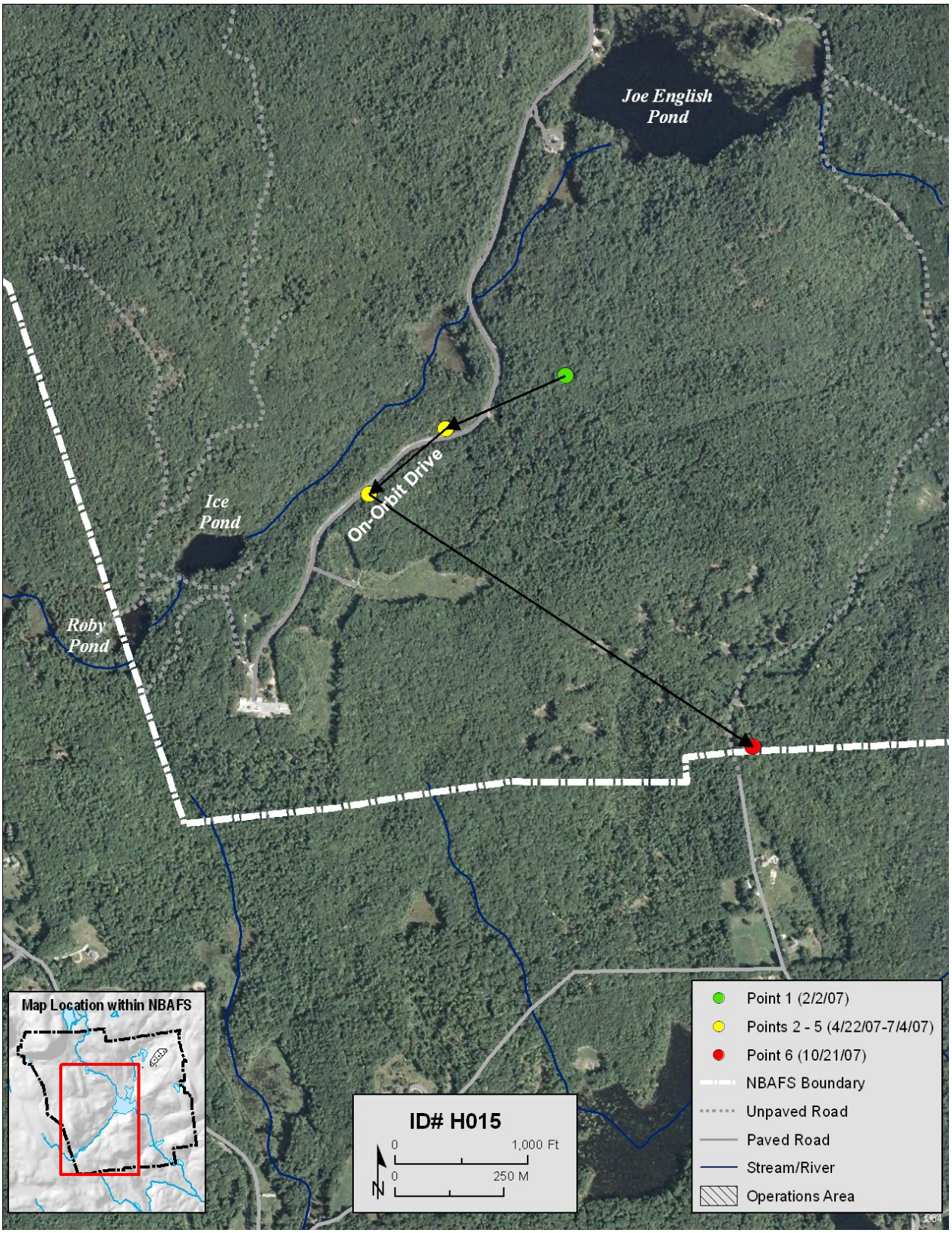

FIGURE A12 Movements of Adult Female H015 on New Boston Air Force Station in 2007

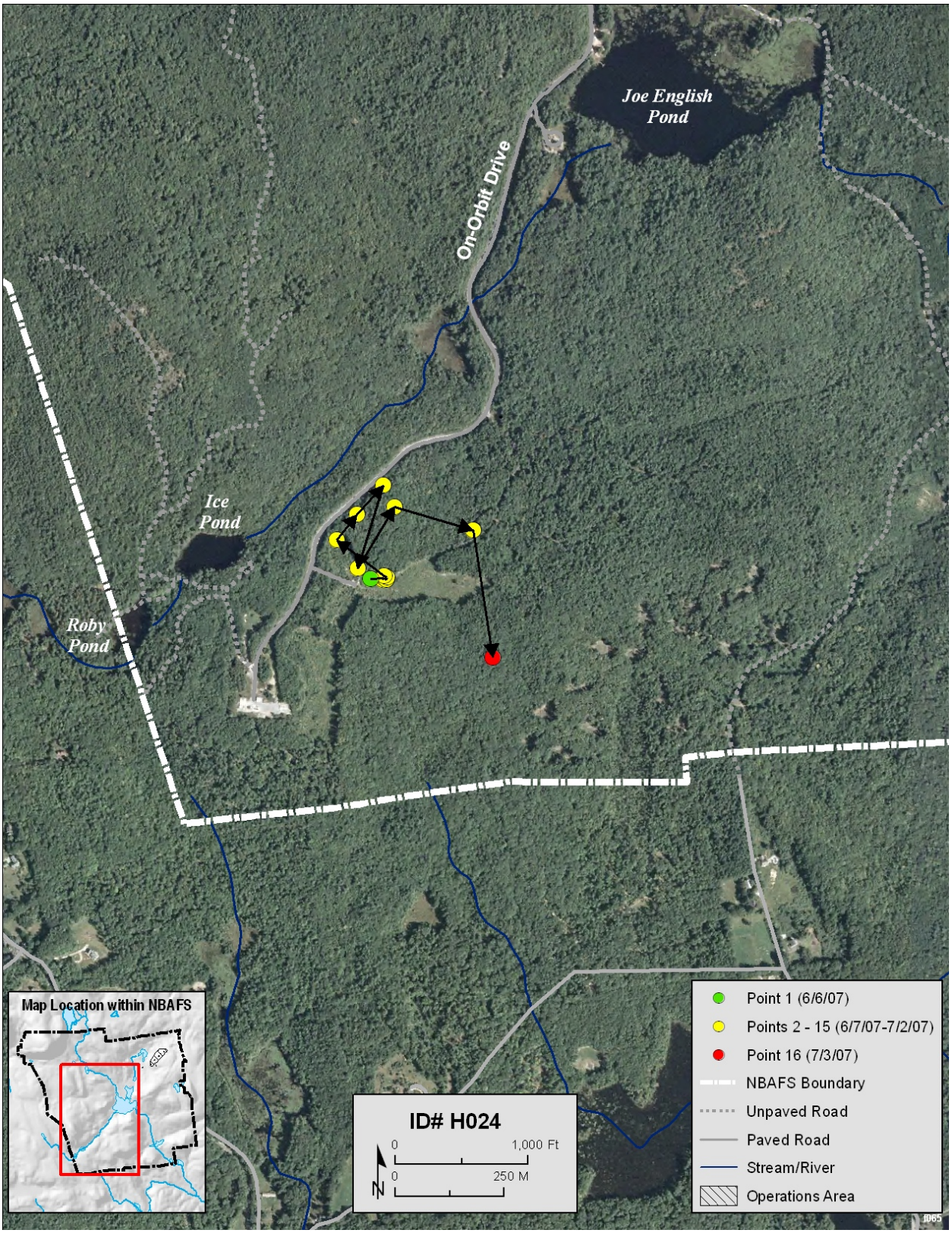

FIGURE A13 Movements of Adult Female H024 on New Boston Air Force Station in 2007

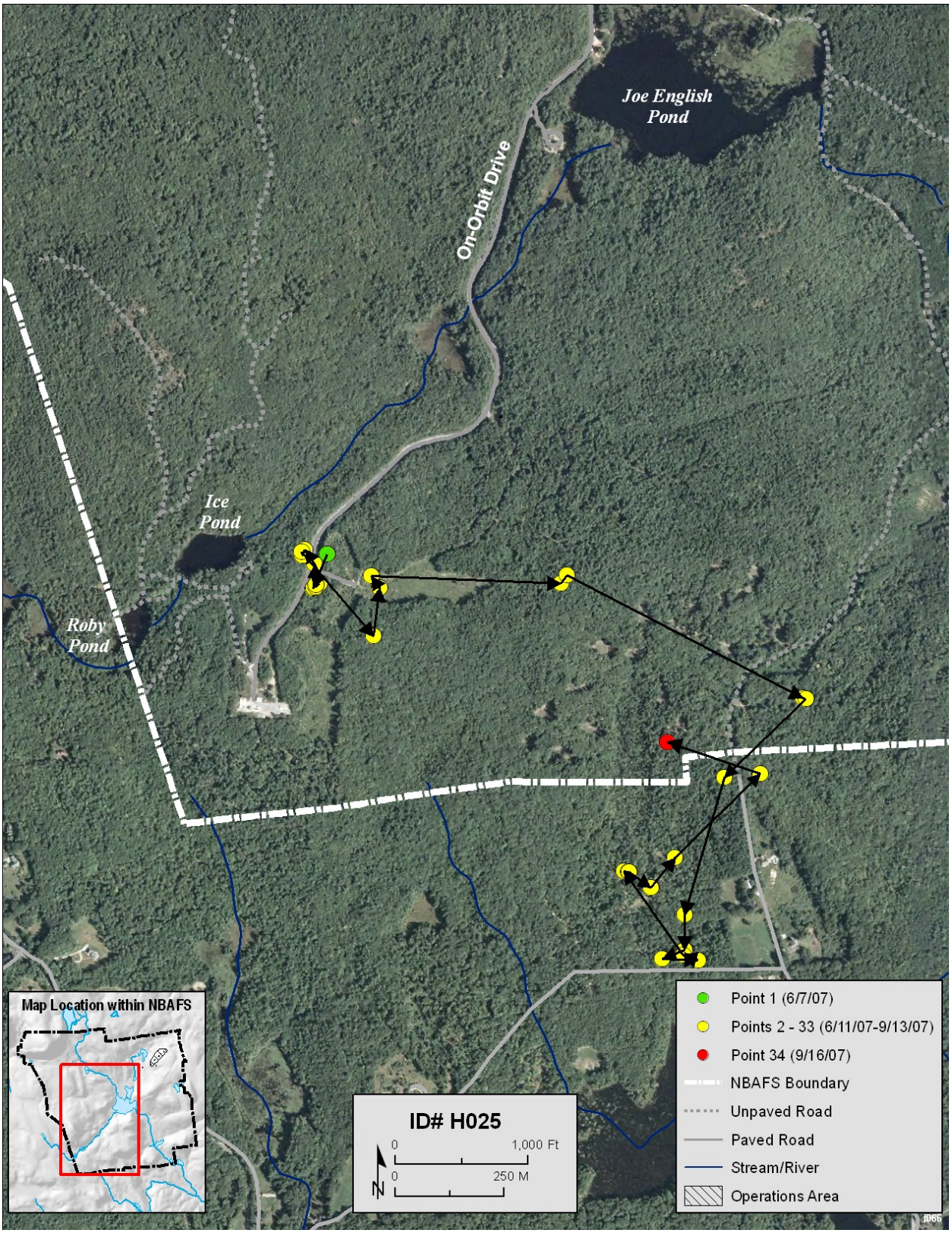

FIGURE A14 Movements of Adult Female H025 on New Boston Air Force Station in 2007

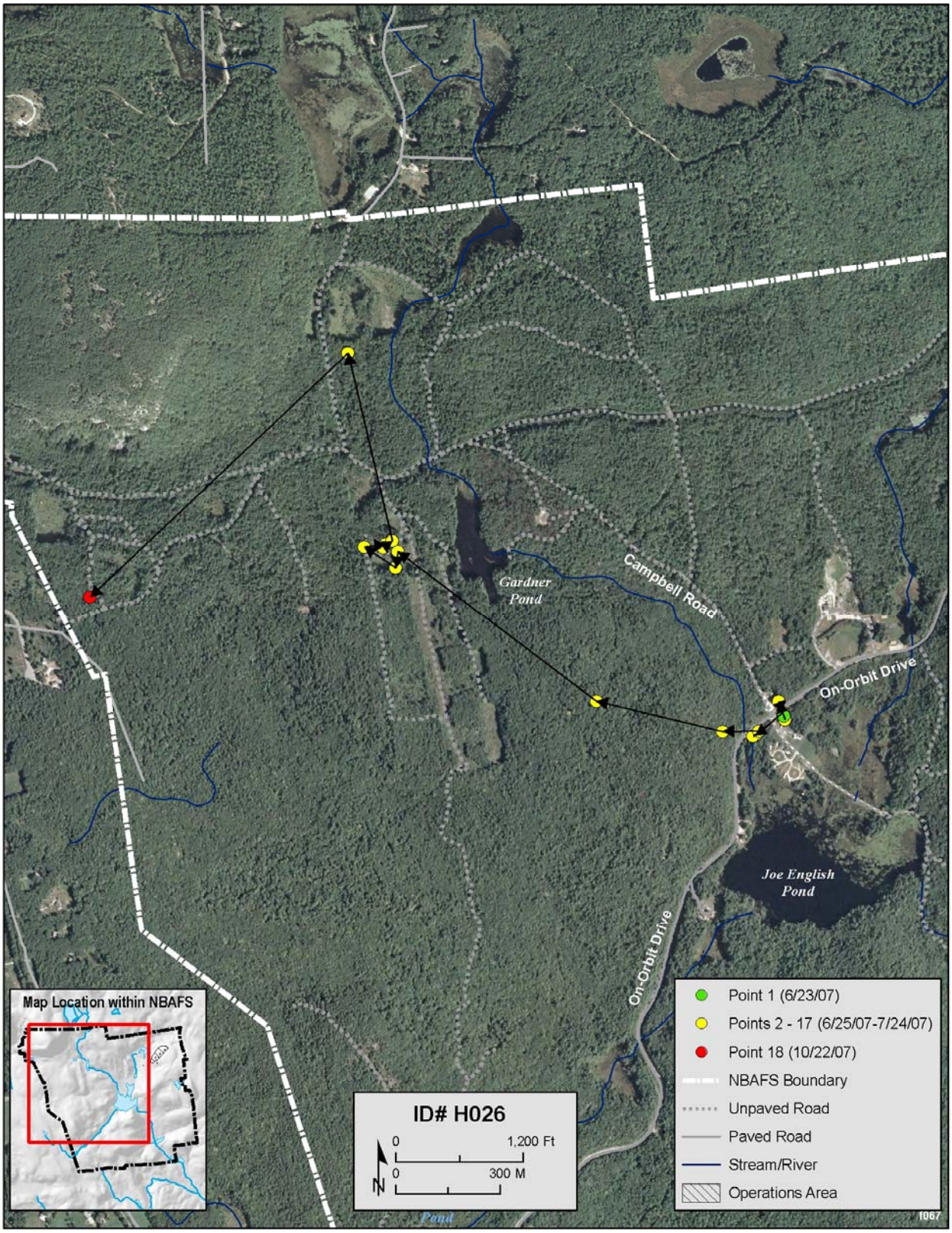

FIGURE A15 Movements of Adult Male H026 on New Boston Air Force Station in 2007

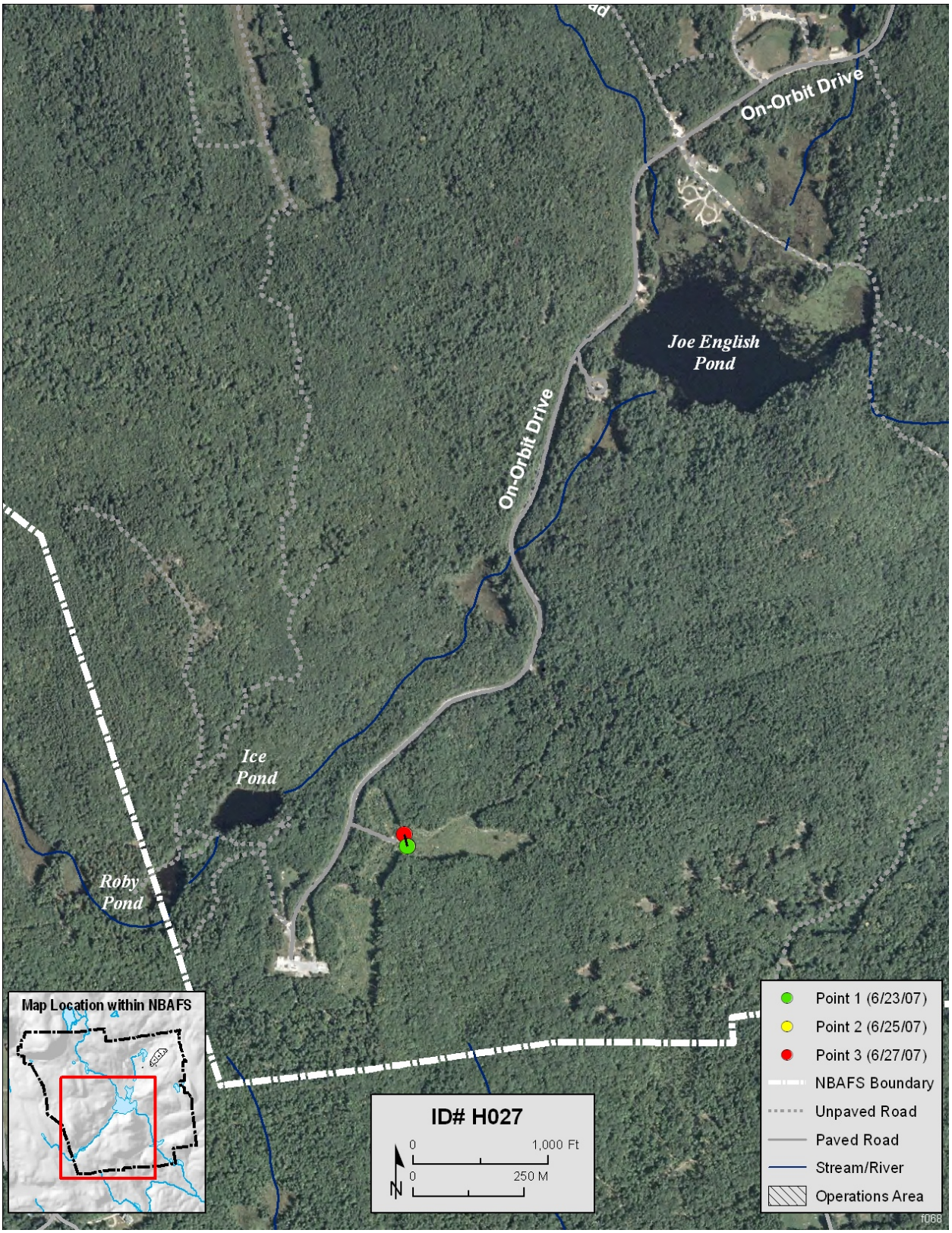

FIGURE A16 Movements of Adult Female H027 on New Boston Air Force Station in 2007

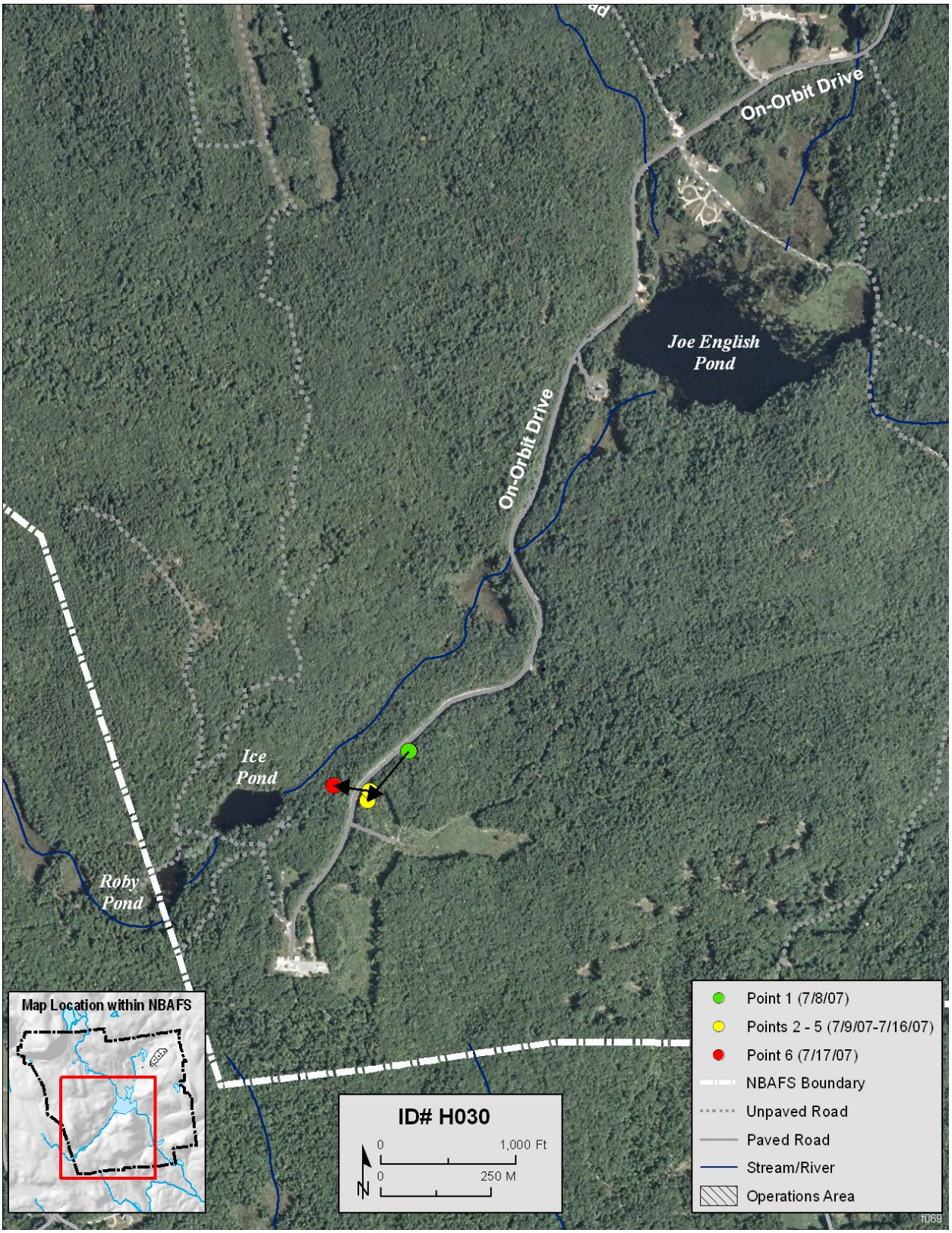

FIGURE A17 Movements of Adult Female H030 on New Boston Air Force Station in 2007

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