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Inventory of Mammals (Excluding Bats) of Thomas Stone National Historic Site

Natural Resource Technical Report NPS/NCBN/NRTR—2010/315

ON THE COVER
Virginia opossum (*Didelphis virginiana*) in Thomas Stone National Historic Site
Photograph by Tressa Dolbeare

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Natural Resource Technical Report NPS/NCBN/NRTR—2010/315

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Executive Summary

A survey of mammals (excluding bats) at Thomas Stone National Historic Site (THST) was conducted from 2002 to 2003 to document the presence of ≥ 90% of the mammals in the park, describe species distributions, relative abundances, and habitat-specific richness, and provide recommendations for management and conservation. Surveys relied on live trapping with Sherman and Tomahawk traps for small to medium-size mammals, the use of pitfall traps to capture small shrews, direct observation of individuals and their sign (tracks, scats), and remote photography. We identified two principal habitats – grassland (fields) and deciduous forest – and less expansive tracts of mixed deciduous-coniferous forest, wind-disturbed deciduous forest, and additional targeted locations for sampling.

Twelve species of mammals were either captured or observed within THST, all new records (species) for the park. Altogether, six orders and nine families of mammals are represented by these species. These species constitute 60% (12 of 20) of those predicted to occur in the park. New species we recorded include the Virginia opossum (*Didelphis virginiana*), northern short-tailed shrew (*Blarina brevicauda*), southeastern shrew (*Sorex longirostris*), eastern mole (*Scalopus aquaticus*), eastern cottontail (*Sylvilagus floridanus*), meadow vole (*Microtus pennsylvanicus*), white-footed deermouse (*Peromyscus leucopus*), woodchuck (*Marmota monax*), eastern gray squirrel (*Sciurus carolinensis*), red fox (*Vulpes vulpes*), raccoon (*Procyon lotor*), and white-tailed deer (*Odocoileus virginianus*).

THST supports low diversity and abundances of small mammals, in part due to the lack of diversity in habitat types. The white-footed deermouse is the most abundant and widespread species, accounting for 76% of all individuals captured by Sherman and pitfall traps. The generally common and widespread northern short-tailed shrew, a habitat generalist, was neither widespread nor abundant in the park. Grassland (managed fields) supported more species than other principal habitat types, although many of the grassland species occupy grassland-deciduous forest edge habitat. The eastern cottontail, eastern gray squirrel, woodchuck, and white-tailed deer are widely distributed within the park.

Additional inventory and monitoring work should be conducted to determine the status of a number of species either detected in low numbers – the northern short-tailed shrew, southeastern shrew, and meadow vole – or not confirmed but that may exist within the park, at least seasonally – North American least shrew (*Cryptotis parva*), woodland vole (*Microtus pinetorum*), house mouse (*Mus musculus*), brown rat (*Rattus norvegicus*), southern flying squirrel (*Glaucomys volans*), gray fox (*Urocyon cinereoargenteus*), striped skunk (*Mephitis mephitis*), and long-tailed weasel (*Mustela frenata*). A concerted effort should be directed toward documenting the distribution of the southeastern shrew in the park with greater use of pitfall traps (only after proper archeological compliance or oversight has been completed). In addition, the following resource management strategies might be considered, continued, or enhanced: 1) maintaining diverse herbaceous communities by careful attention to mowing and burning schedules; 2) periodically monitoring buildings and adjacent areas for presence of the exotic house mouse and brown rat; and 3) monitoring groundhog populations and, if necessary, using appropriate management practices (e.g., live trapping and relocation) to remove problematic individuals; and 4) monitoring and, if necessary, using management practices to regulate the white-tailed deer population to ensure the preservation of vegetation communities

and understory cover important to mammals and birds. White-tailed deer are of potential public health significance because they serve as hosts for the adult breeding black-legged (deer) tick that is the vector for the etiologic agent (the spirochetes, *Borrelia burgdorferi*) of Lyme disease.

Acknowledgments

Tressa Dolbeare, M.S. student at FSU and co-author of this report, under the supervision of the senior author conducted the bulk of the field work and prepared voucher specimens for the FSU mammal museum. Rijk Morawe, Chief of Natural and Cultural Resources Management, assisted in the field and provided information on the park, collection permits, maps, and other materials. We thank him also for the time he spent introducing us to the park and discussing the project with us. We are indebted to John Karish, Beth Johnson, Sara Stevens, and the National Park Service for funding the project. Frostburg State University provided much-appreciated matching funds and logistical support.

Introduction

Surveys of mammals in coastal and mid-Atlantic national parks in the Northeast Region are in compliance with the Natural Resource Inventory and Monitoring Program of the National Park Service (NPS 1998). One of the five long-term goals established by this program is to complete baseline inventories of basic biological and geophysical natural resources for the national parks. During Phase 1 of the natural resource inventory the National Park Service (NPS) has set an objective of documenting the presence of 90% of all vascular plant and vertebrate animal species occurring within a park's boundaries. Surveys will attempt to confirm the existence of currently listed species and document the presence of additional expected species. Of particular importance is the detection of any threatened and endangered species that merit special attention. Data collected can be used by park natural resource specialists for management and planning in the proper stewardship of the park.

We conducted a survey of mammals (except bats, order Chiroptera) in Thomas Stone National Historic Site (THST) in 2002. The park lies in the Coastal Plain physiographic province in Charles County, Maryland, approximately 7 km (4 miles) west of La Plata and 40 km (25 miles) south of Washington, D.C. (Figure 1). The site was authorized by Congress as a unit of the NPS in the Act of November 10, 1978 and opened in 1992. The park's strategic plan (NPS 2004) indicates the need for preserving and protecting the resources of the park and acknowledges the requirement for inventory and monitoring of natural resources.

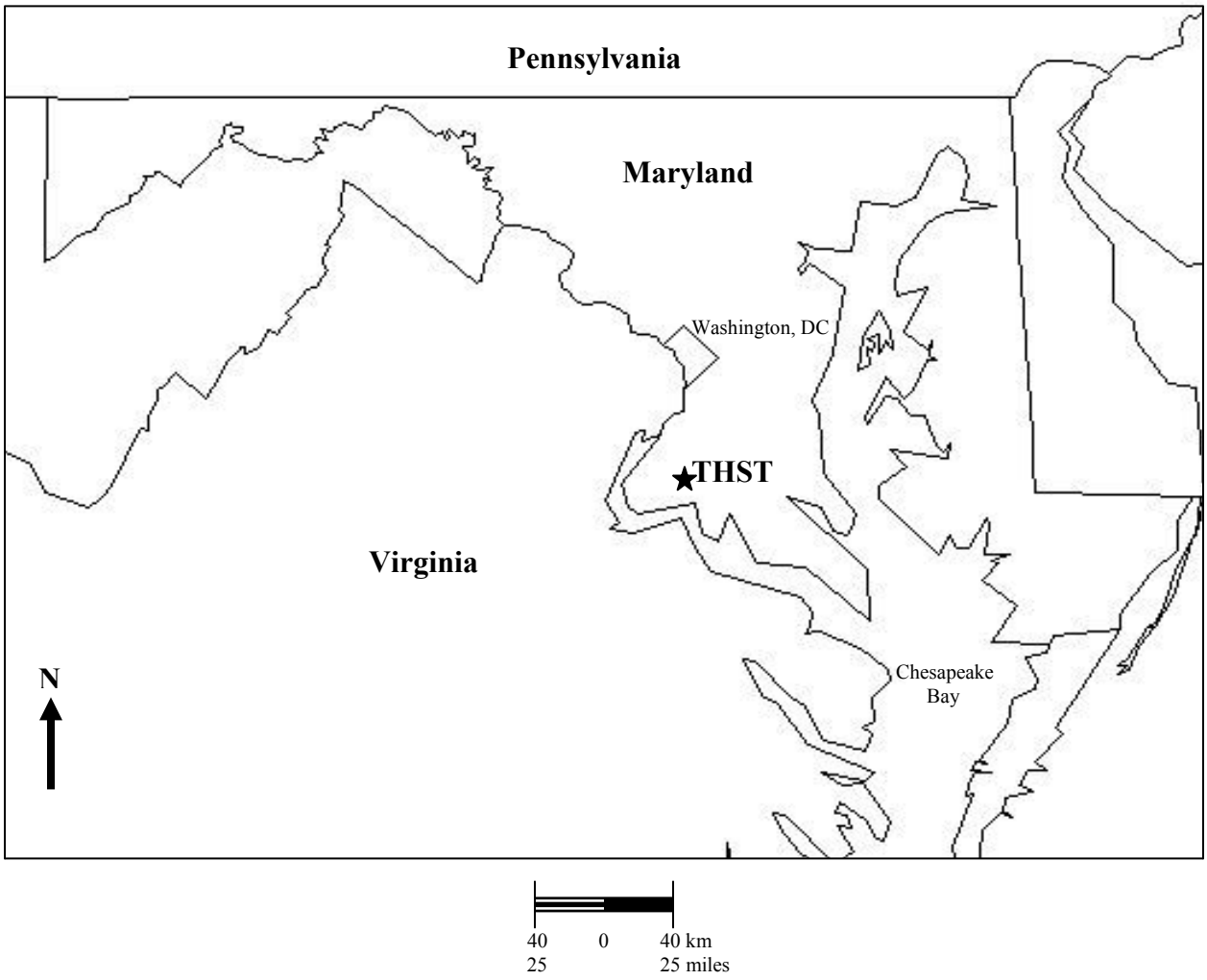


Figure 1. Location of Thomas Stone National Historic Site (THST) in Maryland.

Study Area and Habitats

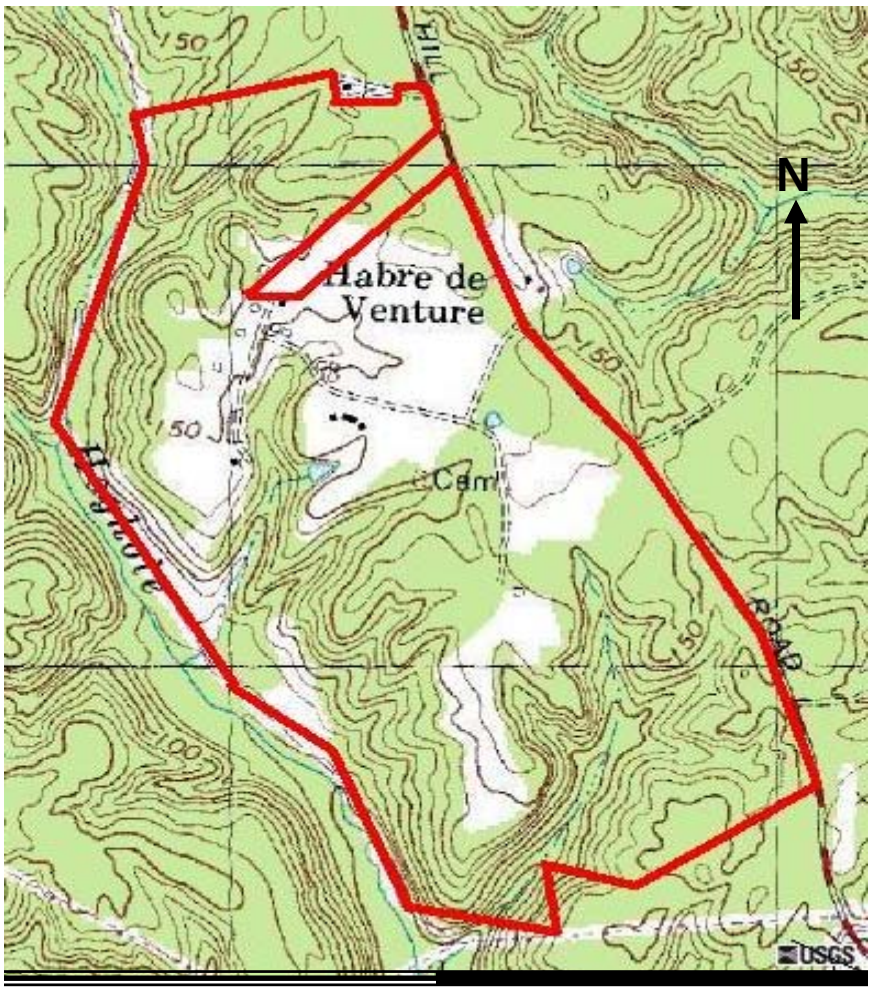
The Thomas Stone National Historic Site is located in Charles County, Maryland, approximately 7 km (4 miles) west of La Plata and 40 km (25 miles) south of Washington, D.C. It consists of 130 ha (322 acres) of primarily open grasslands (fields) and upland forests. Dominant woody vegetation includes sweet gum (*Liquidambar styraciflua*), American holly (*Ilex opaca*), red oak (*Quercus rubra)* and beech (*Fagus spp).* Elevation ranges from 15 m (50 feet) to 52 m (170 feet – R. Morawe, pers. comm., Thomas Stone National Historic Site) (Figure 2).

Delineation of habitats

The recognition of major habitat types allowed stratification of the sampling effort in THST. This permitted a representative and comprehensive survey of the small mammal fauna by increasing the efficiency with which individual species were detected.

Two principal habitat types, managed fields (grasslands) and deciduous forest, constituted the bulk of the park and were identified for inventorying small mammals in THST (Figure 2). In addition, small tracts of mixed deciduous-coniferous forest and severely wind-disturbed deciduous forest (the result of Hurricane Isabel in September 2001) were sampled.

The secure NPSpecies website, https://science1.nature.nps.gov/npspecies, lists vascular plants certified for the park. Common grasses in fields include little bluestem (*Schizachyrium scoparium*), nodding fescue (*Festuca subverticillata*), and "panic grass" (*Panicum* spp.). Dominant woody vegetation in deciduous forest includes sweetgum, tulip tree (*Liriodendron tulipifera*), oaks (*Quercus* spp.), American beech (*Fagus grandifolia*), American holly, and flowering dogwood (*Cornus florida*). The tract of mixed deciduous-coniferous forest is characterized by many of the same taxa and Virginia pine (*Pinus virginiana*).



0.5 mile 0 0.5 mile
0.8 km 0.8 km

Figure 2. USGS topographic map of Thomas Stone National Historic Site outlined in red.

Methods

Sampling Protocol

Sampling sites were located within the two principal habitat types, mixed deciduous-coniferous tract, and disturbed area of the deciduous forest to permit stratified sampling. Habitats initially were identified by aerial photo (Figure 3) and ground-truthed before final selection of sampling sites. The number of sampling locations (sample units) was dependent on number, size, and distribution of habitat types and constraints imposed by equipment and personnel.

To identify sampling points a systematic grid (composed of 30 x 30-m cells) of UTM coordinates was overlaid on an aerial photograph that depicted habitat types (NPS 2000; Figure 3). Points on the grid, within a habitat type, were selected without replacement by the generation of random numbers representing grid cells (Rudran and Foster 1996). Once selected on a map, a sampling point was identified in real space using a Garmin 12 or comparable GPS unit. Portions of the park frequented by the public generally were removed from consideration as sampling locations after the initial visit.

Sampling of small mammals relied primarily on capture with rat-sized (7.6 x 8.9 x 22.9 cm) Sherman live traps. Sherman live traps are generally highly effective for capture of rodents and large shrews such as *Blarina* spp. (Mitchell et al. 1993). Pitfall traps were used to capture shrews and small mammals < 10 g (Kirkland and Sheppard 1994). Pitfalls for shrews were used as kill-type traps containing 3-5 cm of water because careful measurements and examination of skull morphology, dentition, and internal anatomy were required for identification of species, sex, and reproductive condition (Caldwell and Bryan 1982).

Sherman traps were configured at sampling points in randomly positioned linear transects and grids (Table 1; Appendices A and C), with a trap interval of 10 or 15 m. Trap configuration and number of traps (i.e., grid size or transect length) was dependent on habitat type, patch size, and availability of traps. Transects were used where practical because they traverse more home ranges per effort than grids and are especially appropriate for inventory work where accurate estimates of abundance or density are not necessary (Jones et al. 1996). Effective sampling area of a grid was computed by adding a boundary strip equal to one-half the trap interval to all four sides of the grid (Krebs 1999). Effective sampling length of a transect was computed by adding one-half trap interval to each end of the transect. Sampling periods of consecutive days of trapping ranged from 1 to 4 days. This sampling regime permitted estimates of species richness and relative abundance (unique individuals per 100 trap nights) for the principal habitat types. While sampling for small mammals at designated locations, we also observed and noted sign of larger mammals; species, location, and date for each such observation were recorded.

Muskrat- (small – 15.2 x 15.2 x 48.3 cm), raccoon- (medium - 25.4 x 30.5 x 81.3 cm), and bobcat-size (large – 38.1 X 50.8 X 106.7 cm) Tomahawk live traps were used to capture mammals of squirrel size and larger, but particularly to target mesocarnivores such as raccoons (*Procyon lotor*) and red (*Vulpes vulpes*) and gray (*Urocyon cinereoargenteus*) foxes. One to several of these traps were placed in small mammal (Sherman) trapping grids and transects (Appendix D) and opportunistically in habitats where mammal sign was detected or where habitat features suggested the presence of larger species. Pitfall traps were arranged in arrays. Each array was 10 m long and consisted of a silt fence and pitfall trap (#10 vegetable can) at

each end and in the middle. Each array was associated spatially with a Sherman trap transect. Remote cameras were used sporadically to document the presence of larger, secretive and elusive species where sign was evident.

Dominant vegetation, percent canopy cover, percent ground cover, degree of disturbance (e.g., primary or secondary forest or plantation, agricultural use of grassland), soil type, presence of rock piles, topography and elevation were noted for each sampling site at 5-15 (proportional to the number of Sherman traps) random locations within Sherman live-trap transects and grids (McDiarmid and Wilson 1996; Barry et al. 1999; Boyce 2001). These detailed observations were recorded in the MS Access electronic database as baseline habitat information.

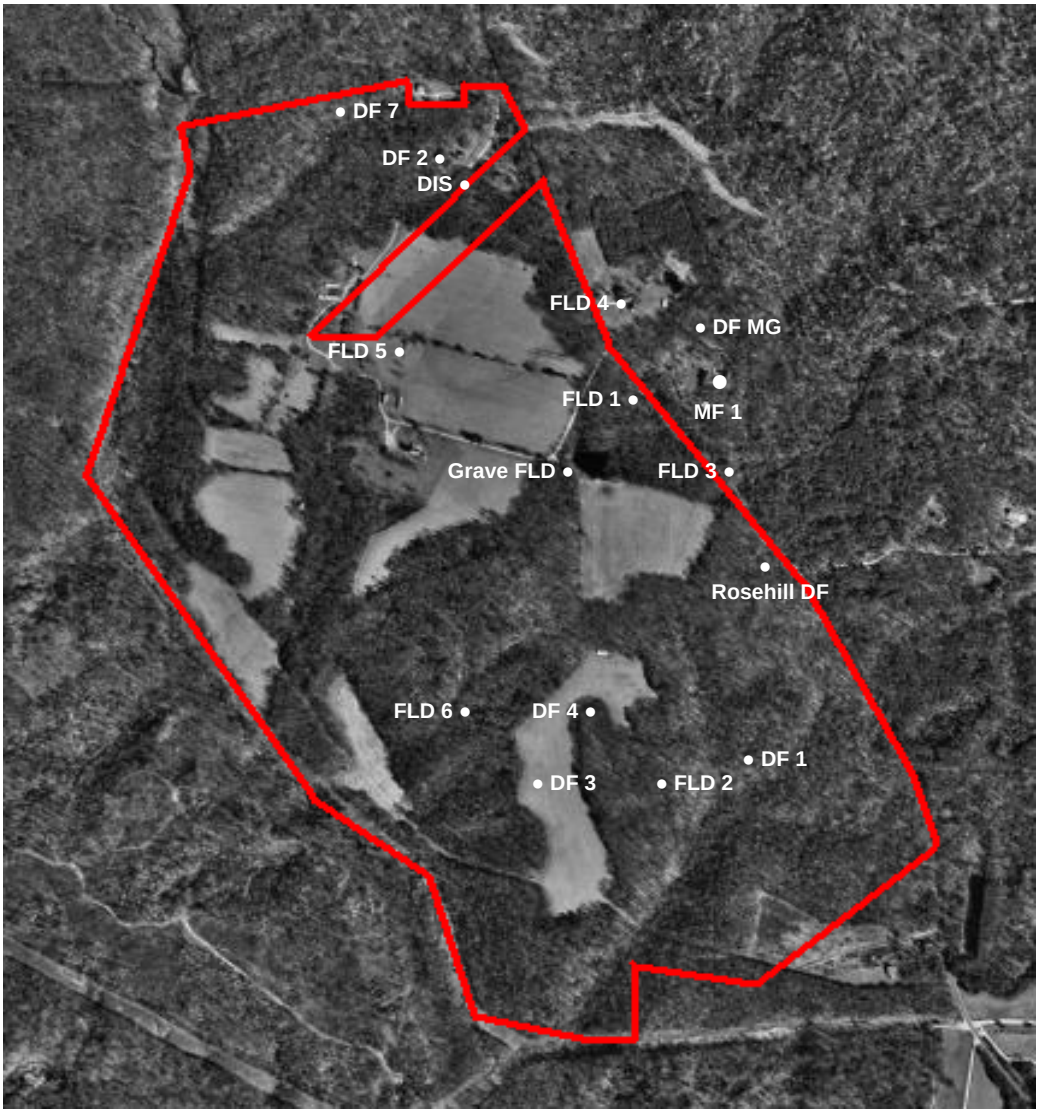


Figure 3. USGS aerial photograph of Thomas Stone National Historic Site showing points sampled in 2002 and 2003. DF = deciduous forest, DIS = wind-disturbed area of deciduous forest, FLD = field, MF = mixed deciduous-coniferous forest. MG = main gate.

Table 1. Sherman trap configuration for sampling sites at Thomas Stone National Historic Site for 2002 and 2003.

			Trap Nights			
Year	Habitat/Site[1]	Trap Configuration[2]	Sherman	Tomahawk[3]	Pitfall	Museum Special
2002						
	FLD 1	Grid (0.30)	60			
	DIS	Tran (0.40)	80			
	DF 1	Tran (0.30)	60			
	DF 2	Tran (0.30)	120	8^{m}		
	DF 3	Grid (1.00)	400	16^{m}		
	FLD 2	Grid (1.00)	400	12^{m}		
	FLD 3	Grid (0.49)	147	12^{m}		
	MF 1	Grid (0.49)	147	12^{m}		
	DF 3	Grid (1.00)	400	12^{m}		
2003						
	FLD 4	Tran (0.30)	40			20
	DF 7	Grid (1.10)	98			
	Rosehill DF	Tran (0.45)	120	12^{s}	36	
	Grave FLD	Tran (0.45)	120			
	DF MG	Tran (0.14)	54	$18^{s},7^{l}$	48	9
	FLD 5	Tran (0.15)	60	2^{l}		
	FLD 1	Tran (0.20)	60			
	DF 2	Tran (0.45)	90	3^{s}		
	FLD 3	Tran (0.45)	60			
	FLD 6	Tran (0.36)	72			
	DF 4	Tran (0.36)	72			

[1] DF = deciduous forest, DIS = wind-damaged deciduous forest, FLD = field, MF = mixed deciduous-coniferous forest. MG = near Main Gate of the park.

[2] Numbers in parentheses for Sherman trap configuration represent effective sampling areas in ha for grids (Grid) and effective sampling lengths in km for transects (Tran).

[3] Tomahawk live traps ^{s} = small, ^{m} = medium, ^{l} = large

Sherman traps were baited with a combination of peanut butter and rolled oats. Tomahawk traps usually were baited with canned cat food. Pitfall traps and remote camera locations were not baited. Captured individuals of small species (those in Sherman and pitfall traps) were removed from traps, identified to species, weighed using a Pesola scale, and examined for age, sex, and reproductive condition (Jones et al. 1996). Individuals captured in Tomahawk traps were identified to species and examined for age, sex, and reproductive condition. Since recognition of individuals was used for determining relative abundances and measures of species diversity, captured individuals of small mammal species were marked by toe-clipping (Rudran 1996; ASM 1998). To obtain meaningful scientific data about shrews, they were collected by kill trapping (pitfall traps). Release of captured individuals (other than shrews or accidental deaths) was immediate at the capture location after measurements were obtained. Live-trapping, handling procedures, pitfall trapping, and specimen collection were conducted humanely (Rudran and Kunz 1996), consistent with the animal handling guidelines of the American Society of Mammalogists (ASM 1998), and were approved by the Institutional Review Board/Animal Care and Use Committee (IACUC # A2002-001) at Frostburg State University (FSU). Proper precautions were taken by investigators to prevent human injury and exposure to disease, especially rabies, Lyme disease, hantaviral pulmonary syndrome (HPS), and human ehrlichiosis (Gage et al. 1995; Mills et al. 1995; Kunz et al. 1996). Animals found dead in traps (most frequently in pitfalls), if salvageable, were collected, prepared, deposited, and maintained in the Frostburg State University mammal museum.

Yearly Sampling Protocol

Sampling using Sherman and medium Tomahawk live traps was conducted in two principal habitats, managed fields (grassland) and deciduous forest, and small tracts of mixed deciduous-coniferous forest and the disturbed deciduous forest in seven sampling periods from May through August 2002 (Table 1; see Appendix A). At eight sampling points Sherman traps comprised five grids (3 x 10, 5 x 20, 7 x 7, or 10 x 10 traps each) covering a total of 3.3 ha (8.1 acres) and three transects of variable length along 1.0 km (0.6 miles). Sherman trap interval was 10 m for all transects and grids. Trap nights totaled 1,814 trap nights with Sherman traps and 88 with Tomahawk traps. In addition to these sampling periods, direct observations of mammals (or their sign) and remote photography yielded records of mammals in May-July.

Sherman, small and large Tomahawk live traps, pitfall traps, and Museum Special snap traps were opened during six sampling periods (two to four nights each) from April through October 2003. We sampled managed field (grassland) and deciduous forest habitats (Table 1; Appendixes C and D). At 11 sampling locations where Sherman traps were used, one grid (7 x 7 traps) covered 1.1 ha (2.7 acres), and 10 transects of variable length spanned a total of 3.3 km (2.0 miles). Sherman traps were placed randomly at the barn location in an attempt to capture house mice and rats. Traps were spaced at 15-m intervals in grids and transects except for FLD 1 (10-m intervals), which was sampled at a different point in 2002 (Appendixes A and C). Twenty-one pitfalls (7 arrays) total were used at two locations (Appendix D). Three locations were sampled with small Tomahawk traps, and two were sampled with large Tomahawk traps (Appendix D). Pitfall arrays and Tomahawk traps were spatially associated with Sherman traps. Museum Special traps (Forestry Suppliers, Inc., Jackson, Mississippi; were used at two locations for a total of 13 trap nights to obtain a voucher specimen of the white-footed mouse (*Peromyscus leucopus*). Trap nights totaled 846 with Sherman traps, 33 with small Tomahawk traps, 9 with large Tomahawk traps, 84 with pitfall arrays, and 29 with Museum Special traps in 2003.

Compilation and analysis of data

Species distributions among habitats were summarized. Marking and recognition of individuals captured in Sherman traps permitted estimates of relative abundance for small species for principal habitat types.

Data on habitat characteristics and all mammals captured or observed were stored in an electronic database (Microsoft Access). Voucher specimens were assigned NPS accession numbers for THST, prepared, and accessioned into the mammal museum at Frostburg State University. Color photographs taken with digital and remote cameras were stored and copies provided to the Chief of Natural and Cultural Resources Management of the park.

Results

Historical Records and Predicted Species

The National Park Service's NPSpecies database (https://science1.nature.nps.gov/npspecies) contains historical records of plants and animals for each park. Publications and park records pertaining to the mammals of THST were sought, but no records were found. Similarly, the NPSpecies database contains no certified records of mammals for the park. We have listed species predicted to occur in THST (Table 2) based on known distributions and habitat preferences (Paradiso 1969; Linzey 1998). This list contains 20 species within six orders and 12 families of mammals (excluding bats).

Field Survey

Our survey of 2002-2003 resulted in 12 species of mammals either captured or observed within THST. These results represented 12 new species records for the park (Table 2). These species belong to six orders and nine families of mammals.

In 2002 five species of mammals were captured a total of 41 times at four of the eight sampling locations (Appendixes A and B). In 2003 15 individuals representing four species of mammals were captured a total of 21 times at five of the 11 sampling locations (Appendixes C, D, and E). Types of habitats, sampling dates, numbers of trap nights, individuals captured, capture frequencies, and relative abundances for mammal species are summarized for each sampling location, by year, are in Appendices A-E.

The most abundant small mammal in THST was the white-footed deermouse, *Peromyscus leucopus.* This species was captured in Sherman traps in both principal habitats, mixed forest, and the disturbed forest (Table 3; Appendixes B and E) and was the most abundant species in all habitats but fields, as well as, the only species captured in the disturbed area. The meadow vole, *Microtus pennsylvanicus*, was the most abundant species in field habitat. Only the southeastern shrew, *Sorex longirostris* (relative abundance = 2.1), was captured in pitfall traps, and the sole capture was in deciduous forest.

Capture frequencies of larger mammals captured in Tomahawk traps were recorded, but relative abundances were not obtained because individuals of these larger species were not marked for individual recognition. The Virginia opossum (*Didelphis virginiana*; 2 captures) and raccoon (*Procyon lotor*; 3 captures), were the only species captured in Tomahawk traps, and all captures occurred within deciduous forest habitat (Appendixes B and E).

Eleven species of mammals were documented based on either observation or sign during the study. Three species, the white-tailed deer (*Odocoileus virginianus*), raccoon, and domestic dog (*Canis lupus*), were documented by remote camera (Table 4) in deciduous forest near the historical house. Deer were photographed on three occasions in October-December 2003, and a single photographic record of a raccoon was obtained in October 2003. Dogs were photographed on three occasions in October 2003 but were assumed to be from nearby residential areas and were not included in the inventory.

Table 2. Comparison of predicted species for Thomas Stone National Historic Site (based on Paradiso 1969 and Webster et al. 1985) and species observed during this study (2002-2003). Taxonomy and common names follow Wilson and Reeder (2005).

Order Family	Species Name	Common Name	Predicted	THST Observed
Didelphimorphia				
Didelphidae	Didelphis virginiana	Virginia opossum	X	X
Soricomorpha				
Soricidae	*Blarina brevicauda*	Northern short-tailed shrew	X	X
	Cryptotis parva	North American least shrew	X	
	Sorex longirostris	Southeastern shrew	X	X
Talpidae	*Scalopus aquaticus*	Eastern mole	X	X
Lagomorpha				
Leporidae	*Sylvilagus floridanus*	Eastern cottontail	X	X
Rodentia				
Cricetidae	Microtus pennsylvanicus	Meadow vole	X	X
	Microtus pinetorum	Woodland vole	X	
	Peromyscus leucopus	White-footed deermouse	X	X
Muridae	*Mus musculus*	House mouse	X	
	Rattus norvegicus	Brown rat	X	
Sciuridae	*Glaucomys volans*	Southern flying squirrel	X	
	Marmota monax	Woodchuck	X	X
	Sciurus carolinensis	Eastern gray squirrel	X	X
Carnivora				
Canidae	*Urocyon cinereoargenteus*	Gray fox	X	
	Vulpes vulpes	Red fox	X	X
Mephitidae	*Mephitis mephitis*	Striped skunk	X	
Mustelidae	*Mustela frenata*	Long-tailed weasel	X	
Procyonidae	*Procyon lotor*	Raccoon	X	X
Artiodactyla				
Cervidae	*Odocoileus virginianus*	White-tailed deer	X	X

Table 3. Summary of numbers and relative abundances[1] of small mammals captured with Sherman traps among three principal habitat types[2] and disturbed forest at Thomas Stone National Historic Site, 2002-2003.

		Habitat			
Species Name	Common name	FLD	DF	MF	DIS
Blarina brevicauda	Northern short-tailed shrew		3(0.21)		
Microtus pennsylvanicus	Meadow vole	4(0.39)			
Peromyscus leucopus	White-footed deermouse	1(0.07)	18(1.77)	4(2.72)	3(3.75)
Total number of trap nights		1,019	1,414	147	80

[1] Relative abundance calculated as the number of individuals per 100 trap nights and shown in parentheses

[2] FLD = fields, DF = deciduous forest, MF = mixed deciduous-coniferous forest, DIS = wind-disturbed deciduous forest

Table 4. Mammal sightings or sign in Thomas Stone National Historic Site, 2002-2003**.**

		Means of Observation		
Species Name	Common name	Direct Observation	Sign or Remains	Remote Camera
Blarina brevicauda	Northern short-tailed shrew	X		
Scalopus aquaticus	Eastern mole		X	
Sylvilagus floridanus	Eastern cottontail	X		
Microtus pennsylvanicus	Meadow vole	X		
Peromyscus leucopus	White-footed deermouse	X		
Sciurus carolinensis	Eastern gray squirrel	X		
Marmota monax	Woodchuck	X		
Canis lupus[a]	Domestic dog	X		X
Vulpes vulpes	Red fox		X	
Procyon lotor	Raccoon	X		X
Odocoileus virginianus	White-tailed deer	X	X	X

[a] Not included in the inventory.

Eastern gray squirrels (*Sciurus carolinensis*) were observed frequently in open, grassy areas within the park or on roads adjacent to wooded habitat. Eastern cottontails were seen almost exclusively in grassy areas. Woodchucks (*Marmota monax*) were seen most often in grassy areas. Tracks of a red fox (*Vulpes vulpes*) were observed in June 2002 in a grassy area near the maintenance facility. A juvenile raccoon was observed in the disturbed area of the deciduous forest in May 2002. We observed individuals and scat of white-tailed deer most often in wooded habitat, but deer also were frequently spotted in fields. Eastern mole tunnels were observed near the historic house.

Low species richness and relative abundances precluded any meaningful quantitative assessment of habitat-specific species diversity of small mammals. Including captures of opossums and raccoons in Tomahawk traps, deciduous woodland yielded the greatest number of species captured – 4. Two or fewer species were captured in other principal habitat types. Including all means of capture and observation, grassland supported more species (6) than other habitat types.

Voucher specimens

One specimen each of *Sorex longirostris* and *Peromyscus leucopus* was collected from THST. These specimens were accessioned into the FSU mammal museum in 2004. Data on these specimens are as follows:

1) Species = *Sorex longirostris* (southeastern shrew), sex = unknown, nature of specimen = skull, NPS accession/catalog number 13/1826, FSU accession number 2671;

2) Species = *Peromyscus leucopus* (white-footed deermouse), sex = female, nature of specimen = skull, NPS accession/catalog number 13/1825, FSU accession number 2674.

Discussion

Species records

With the 12 new records we have documented the presence of 60% (12 of 20) of the non-chiropteran species predicted to occur in THST. We are confident, based on the presence of suitable habitat, that additional surveys and observations will show that the park contains the following: *Glaucomys volans* (southern flying squirrel), *Mephitis mephitis* (striped skunk), and *Mustela frenata* (long-tailed weasel) which we were unable to confirm. *Mus musculus* (house mouse) and *Rattus norvegicus* (brown rat) could be park residents, at least seasonally, in places that were not sampled within or closely associated with park buildings. In addition, *Urocyon cinereoargenteus* (gray fox) could be present, even if only as transient individuals that are resident in nearby wooded tracts.

Habitat generalists

The white-footed mouse is a woodland species that can be found in a variety of habitats, commonly brushy habitat or wooded areas dominated by deciduous species and ample, downed woody debris and is found in low densities in grassy habitats (Barry and Francq 1980; Lackey et al. 1985).It was captured in all principal habitat types, more frequently than any other species in Sherman traps in deciduous forest, and was the only species captured in mixed and disturbed deciduous forest habitats. Only one was captured in fields. This species commonly occupies brushy habitat or wooded areas dominated by deciduous species and ample, downed woody debris and is found in low densities in grassy habitats (Barry and Francq 1980; Lackey et al. 1985).

Although the northern short-tailed shrew occurs within a wide variety of habitats throughout its range (George et al. 1986), we captured this species in only one habitat - deciduous forest - and in low numbers. Its apparent rareness in THST forest may be due to a poorly developed leaf litter layer, contributing to a dry substrate. Merritt (1987) suggested that short-tailed shrews may avoid dry areas. Mammone (1997) found this species associated with herbaceous ground cover and leaf litter, but not logs in clearcuts and adjacent woodlands in western Maryland. Our failure to capture the short-tailed shrew in field habitat may be due, in part, to low densities of meadow voles, which can be important prey items for shrews (George et al. 1986).

The southeastern shrew is a diminutive species that is captured more commonly with pitfall traps. We captured only one, in a pitfall trap in deciduous forest. Nevertheless, it has been found in a variety of habitats within its range, although it seems to be more abundant in wet areas bordering marshes, swamps or rivers (French 1980). THST would seem to provide limited habitat for this species.

Eastern cottontails, gray squirrels, and woodchucks were observed most often in open, grassy areas within THST. Eastern cottontails are widely distributed among habitats within their range (Chapman et al. 1980), although they prefer old fields, brushy areas, field-woodland edge (Linzey 1998), and early successional habitat (Chapman and Litvaitis 2003). Eastern gray squirrels are most common in mature, intact deciduous and mixed deciduous-coniferous woodlands but use a variety of habitats throughout their range (Koprowski 1994; Linzey 1998; Edwards et al. 2003). Woodchucks typically occupy field-forest ecotone (Kwiecinski 1998).

THST provides large tracts of grassland (fields) and upland forest capable of supporting healthy populations of these three species.

The raccoon and Virginia opossum exhibit a wide breadth of habitat use, with predilection for wooded areas near water (McManus 1974; Lotze and Anderson 1979; Gardner and Sunquist 2003; Gehrt 2003). The paucity of water within the park may explain why these species were not abundant, a few individuals being captured only in deciduous forest and a juvenile raccoon being observed in disturbed forest.

Red foxes traverse a variety of habitats within fragmented landscapes (Cypher 2003). We detected the presence of this species in THST based on tracks of a single individual in a grassy area. Habitat requirements of the red fox would seem to be met in THST by the extensive field and forest tracts and the edge habitat their concurrence provides.

White-tailed deer are cosmopolitan in their habitat affinities, occupying both open and forested habitats (Miller et al. 2003). Nevertheless, they are most often associated with woodlands (Linzey 1998). We observed them (or their sign) most often in woodland, but they also were seen frequently in fields. They appear to be reasonably abundant in THST where large tracts of forest provide concealment and thermal cover and forest and grassland satisfy their foraging needs.

Habitat specialists

The most abundant small mammal in THST grassland was the meadow vole. This mammal is found primarily in open grasslands (Reich 1981; Linzey 1998). Although grassy field covers much of THST, the relative abundance of the meadow vole is low. Numbers may be low because vegetative cover in fields is reduced by periodic management (e.g., mowing – Reich 1981).

Exotic species

Dogs were observed on a few occasions in the park. We suspect that these animals were individuals from adjacent residential neighborhoods. House mice and brown rats were not captured in the park but may be present, at least seasonally, in and around buildings.

Habitat-specific species diversity

The greatest number of species (6) captured or observed, by any means, among habitat types was in grassland, although many of these species occupy grassland-deciduous forest edge habitat. More species (4) were captured in deciduous forest than any other principal habitat type. However, too few captures were made to derive quantitative estimates of measures of habitat-specific species diversity. It is apparent that diversity and relative abundances of small mammal species in THST are low, in part due to the lack of diversity in habitat types and major bodies of water. The white-footed deermouse comprised more than three-fourths of all individuals captured in Sherman and pitfall traps.

Sampling efficiency

Sherman traps are the industry standard for live capture of rodents and shrews of body mass $\geq$ 10 g (Mitchell et al. 1993) and were used with success to capture white-footed mice, meadow voles, and short-tailed shrews in four habitat types. However, for smaller species pitfall traps are

more efficient (Szaro et al. 1988; Kirkland and Sheppard 1994). Unfortunately, these traps must be used as kill traps because small shrews are difficult to identify to species and sex without close examination of the dentition and internal reproductive anatomy. In addition, the placement of pitfall traps is labor-intensive, they must be located and placed under close supervision of park personnel so that archeological remains are not disturbed. Archeology is deemed especially important due to the historical importance of the site (Long Range Interpretive Plan 2005). Therefore, we used these traps on a very limited basis specifically to target small shrews that cannot be captured by any other means. We captured only one individual, a southeastern shrew, in 84 pitfall trap nights.

Tomahawk traps baited with canned cat food can be used effectively to capture medium-size mammals (especially mesocarnivores) that are secretive or elusive. These traps were efficient at capturing opossums and raccoons in THST. Remote cameras were labor-intensive and not very productive but were useful in detecting and confirming the identification of individuals that left sign in frequently traveled terrain. Direct observation, especially while conducting trap sampling, is efficient for detecting sign and medium to large, nonsecretive species.

Conclusions and Management Recommendations

According to the Long Range Interpretive Plan (2005) for THST, one of the three objectives of the General Management Plan established in 1990 (and revised in 1996) for THST is to "manage and protect the natural resources of the site consistent with the need to interpret agrarian lifestyles and re-establish historic landscapes." Our inventory of the mammals of THST addressed and provided for the future attainment of this objective. Most important, it documented the presence of particular species of mammals, noted their habitat associations, described sampling protocol and provides information that can be used to monitor mammal populations, and provides recommendations for their conservation and management.

The park supports low diversity and abundances of small mammals, in part due to the lack of diversity of habitat types. Two of the most common mammals in eastern North America, the northern short-tailed shrew and white-footed deermouse, occur in the park. The ubiquitous white-footed deermouse is reasonably abundant in forested habitat, as expected. However, abundance of the normally common short-tailed shrew is low and its distribution restricted. Meadow voles, usually abundant grassland specialists, were not abundant in THST. Other common species of mammals, such as eastern cottontail rabbits, eastern gray squirrels, woodchucks, Virginia opossums, raccoons, and white-tailed deer, were trapped or observed frequently in their preferred habitats.

The absence of the North American least shrew likely can be attributed to the lack of ample preferred habitat. The least shrew, although found in grassy fields (Whitaker 1974; Linzey 1998), prefers fallow fields (Paradiso 1969).

Additional inventories

Additional inventory and monitoring work should be conducted to determine the status of a number of the species we either detected in low numbers (e.g., the northern short-tailed shrew, meadow vole, southeastern shrew) or could not confirm but that may be present seasonally or in small numbers (North American least shrew, woodland vole, house mouse, brown rat, southern flying squirrel, gray fox, striped skunk, and long-tailed weasel). Buildings should be sampled routinely, especially during winter months, to confirm the status of the house mouse and brown rat. Additional sampling with Sherman traps should confirm the presence of the long-tailed weasel because of the extent of forest-field edge habitat (Paradiso 1969). Additional observation and recording by park personnel will likely confirm the occurrence of the easily detectable striped skunk. The third dimension of forests could be sampled to document the presence/absence of the southern flying squirrel. Sherman traps can be mounted in trees (Barry et al. 1984) using aluminum nails so that safety in future logging operations is not jeopardized. Pitfall trap arrays should be used more extensively for sampling to establish the presence and status of shrew species (e.g., the southeastern shrew). Pitfall traps must be used responsibly and with adequate supervision only after archeological compliance or oversight has been completed so that archeological remains are not disturbed and large numbers of individuals of any single species are not sacrificed.

Habitat Management

Inventory and monitoring activities will continue to provide important information on how habitats should be managed for the conservation of the park's natural resources. Fields should be

maintained and managed carefully to retain healthy populations of small mammals, which in turn sustain larger species. To increase the density of ground cover and presumably the abundance and diversity of small mammals (and their predators, including raptors), some fields might be mowed/burned less frequently if this would not affect the historical and cultural value of THST. Mowing should be scheduled for mid-summer (i.e., mid to late July) after young from the spring birth pulse have matured, dispersed, and established new home ranges and before the late summer breeding season ensues. This could lead to a modest increase in the recreational use of the park for such activities as bird-watching.

Species Management

It does not appear that any species of mammal in THST occurs at such an unusually high density as to pose a difficult management problem. The woodchuck population appears to be healthy. Problematic individuals can be captured with Tomahawk traps and removed. This is usually an effective means of control for individuals of other species (e.g., opossum, raccoon) that become problems around humans and buildings.

Based on frequent sightings and sign, white-tailed deer appear to be abundant in THST. When overabundant, deer potentially pose several problems. These can include an alteration of the stable state of a northern temperate forest (Stromayer and Warren 1997), which can affect understory cover important to mammals and birds. Also, deer serve as hosts to an extraordinary diversity of ectoparasites, including adult, breeding *Ixodes scapularis*, the black-legged tick that is the vector of the etiologic agent for Lyme disease, the spirochete, *Borrelia burgdorferi* (Miller et al. 2003). In light of the low diversity of small mammals in the park, monitoring the deer population (e.g., with pellet-group counts) and understory browse in deciduous forest and edge habitat is recommended. If such monitoring suggests that deer may be altering the habitat to the detriment of other fauna, management practices to control the deer population may be worthy of consideration.

Populations of THST mammals we documented should be monitored, and efforts to confirm the presence or absence of those species expected to be residents should be continued. In addition to the impacts of larger species on systems, such as those described earlier, the roles of small mammals as critical components of biological communities have been recognized for some time (e.g., Chew 1978). Small mammals consume, transport, and deposit spores and mycelia of mycorrhizal fungi (Fogel and Trappe 1978; Maser et al. 1988) and seeds of many plant species, mix soil and decompose organic matter and litter, regulate invertebrate (e.g., insect) populations, and serve as prey for numerous terrestrial and avian predators (Carey and Harrington 2001; Sekgororoane and Dilworth 1995). Management decisions that can affect proper stewardship of natural systems necessarily rely on periodic assessments of species diversity and abundances from inventory and monitoring activities.

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Appendix A. Trapping schedule, habitats, locations, and efforts for 2002 in Thomas Stone National Historic Site.

				Trap Nights	
Dates	Habitat/Site[1]	Location[2]	Sherman Trap Configuration[3]	Sherman	Tomahawk (medium)
5/22 - 5/23	FLD 1	0322488 4266832	Grid (0.30)	60	
5/22 - 5/23	DIS	0322174 4267105	Tran (0.40)	80	
5/22 - 5/23	DF 1	0322586 4266123	Tran (0.30)	60	8
5/28 - 5/31	DF 2	0322221 4267228	Tran (0.30)	120	16
6/11 - 6/14	DF 3	0322331 4266050	Grid (1.00)	400	12
6/25 - 6/28	FLD 2	0322508 4266064	Grid (1.00)	400	16
7/2 - 7/3, 7/5	FLD 3	0322642 4266577	Grid (0.49)	147	12
7/2 - 7/3, 7/5	MF 1	0322612 4266763	Grid (0.49)	147	12
8/7 - 8/10	DF 3	0322331 4266050	Grid (1.00)	400	12

[1] DF = deciduous forest, DIS = wind-disturbed deciduous forest, FLD = field, MF = mixed forest.
[2] UTM coordinates are for middle of grid or one end of transect; zone 18.
[3] Numbers in parentheses for Sherman trap configuration are effective sampling area in ha for grids (Grid) and effective sampling length in km for transects (Tran).

Appendix B. Capture record for mammals caught in Thomas Stone National Historic Site from May through August 2002.

**Sherman live traps were used to capture small mammals and Tomahawk traps to capture *Procyon lotor*.

		Trap Nights					
Habitat/site[1]	Sherman	Tomahawk (medium)	Species Name	Common Name	No. individuals[2]	Total captures	Relative Abundance[3]
FLD 1	60		*Microtus pennsylvanicus*	Meadow vole	4	4	6.7
DIS	80		*Peromyscus leucopus*	White-footed deermouse	3	3	3.8
DF 3	400	12	*Blarina brevicauda*	Northern short-tailed shrew	3	3	0.4
			Peromyscus leucopus	White-footed deermouse	9	20	2.5
			Procyon lotor	Racoon	?	2	-
MF 1	147	12	*Peromyscus leucopus*	White-footed deermouse	4	9	6.1

[1] DF = deciduous forest, DIS = wind-disturbed deciduous forest, FLD = field, MF = mixed forest. Sites from Appendix A not listed here yielded no captures.

[2] ? Indicates that individuals were not marked for recognition upon recapture.

[3] Relative abundance is individuals/100 TNs. Relative abundances are not determined for small captures in Tomahawk traps.

Appendix C. Trapping schedule, habitats, locations, trap configurations, and efforts for Sherman traps for 2003 at Thomas Stone National Historic Site.

Dates	Habitat/Site[1]	Location[2]	Trap Configuration[3]	Trap Nights
4/5 – 4/6	FLD 4	0322435 4266913	Tran (0.30)	40
4/5 – 4/6	DF 7	0321998 4267271	Grid (1.10)	98
7/8 – 7/11	Rosehill DF	0322694 4266447	Tran (0.45)	120
7/8 – 7/11	Grave FLD	0322334 4266612	Tran (0.45)	120
9/5 – 9/7	DF MG	0322599 4266774	Tran (0.14)	54
10/17 – 10/19				
9/5 – 9/7	FLD 5	0322068 4266852	Tran (0.15)	60
10/17 – 10/18				
10/17 – 10/19	FLD 1	0322363 4266780	Tran (0.20)	60
10/17 – 10/19	DF 2	0322273 4267159	Tran (0.45)	90
10/24 – 10/26	FLD 3	0322724 4266539	Tran (0.45)	60
10/24 – 10/26	FLD 6	0322169 4266209	Tran (0.36)	72
10/24 – 10/26	DF 4	0322395 4266176	Tran (0.36)	72

[1] DF = deciduous forest, FLD = field. Grave = Washington gravesite, MG = near Main Gate of the park

[2] UTM coordinates (zone 18) are for middle of grid or one end of transect. See Figure 3 for map of locations.

[3] Numbers in parentheses for Sherman trap configuration are effective sampling area in ha for grids (Grid) and effective sampling length in km for transects (Tran). Trap interval was 15 m except for FLD 1 (10-m interval).

Appendix D. Trapping schedule, habitats, locations, and efforts for Tomahawk, pitfall, and Museum Special traps for 2003 at Thomas Stone National Historic Site.

			Trap Nights		
Dates[1]	Habitat/Site[2]	Location[3]	Tomahawk[4]	Pitfall	Museum Special
4/5 – 4/6	FLD 4	0322435 4266913			20
7/8 – 7/11	Rosehill DF	0322694 4266447	12^{s}	36	
9/5 – 9/7	DF MG	0322599 4266774	$18^{s},7^{l}$	48	9
9/5 – 9/7	FLD 5	0322068 4266852	2^{l}		
10/17 – 10/19	DF 2	0322273 4267159	3^{s}		

[1] Unless otherwise indicated, dates are nights Tomahawk traps were open at the habitat/site.
[2] DF = deciduous forest, FLD = field. MG = near Main Gate of the park.
[3] UTM coordinates (zone 18) are for one end of Sherman trap transect (see Appendix C).
[4] Tomahawk live traps ^{s} = small Tomahawk traps, ^{m} = medium Tomahawk traps.

Appendix E. Capture record for mammals caught in Thomas Stone National Historic Site from April through October 2003.

**Sherman live traps were used to capture small mammals and Tomahawk traps to capture *Procyon lotor*.

	Trap Nights								
Habitat/site[1]	Sherman	Tomahawk[2]	Pitfall	Museum Special	Species	Common Name	No Individuals[3]	Total captures	Relative Abundance[4]
DF 7	98				*Peromyscus leucopus*	White-footed deermouse	3	5	3.1
Rosehill DF	120				*Didelphis virginiana*	Virginia opossum	?	2	-
					Peromyscus leucopus	White-footed deermouse	3	7	2.5
					Procyon lotor	Racoon	1	1	-
Grave FLD	120				*Peromyscus leucopus*	White-footed deermouse	1	1	0.8
DF MG	54	18[s],7[l]	48	9	*Sorex longirostris**	Southeastern shrew	1	1	-
					*Peromyscus leucopus***	White-footed deermouse	1	1	-
DF 2	90	3[s]			*Peromyscus leucopus*	White-footed deermouse	3	3	3.3

[1] DF = deciduous forest, FLD = field, MG = near Main Gate of the park. Sites from Appendix A not listed here yielded no captures.
[2] Tomahawk live traps [s] = small, [m] = medium.
[3] ? indicates that individuals were not marked for recognition upon recapture.
[4] Relative abundance is individuals/100 TNs. Relative abundances are not determined for captures in Tomahawk, pitfall, or Museum Special traps.

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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