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Northeast Region
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Inventory of Mammals (Excluding Bats) of Richmond National Battlefield Park

Technical Report NPS/NER/NRTR—2008/122



ON THE COVER

Striped skunk (*Mephitis mephitis*) in Richmond National Battlefield Park.
Photograph by Avinash Sareen.

Inventory of Mammals (Excluding Bats) of Richmond National Battlefield Park

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Abstract

Frostburg State University (FSU) conducted a survey of the mammals of Richmond National Battlefield Park (RICH) in and east of Richmond, Virginia, in Hanover, Chesterfield, and Henrico counties. The primary purpose of the study, in keeping with the stated objectives of the NPS Inventory and Monitoring Program, was to inventory the mammals, note their habitat associations, and document the presence of $\geq 90\%$ of the species occurring within the park's boundaries. The specific objective of the inventory was to confirm the existence of currently listed species and generate new records for species not detected previously in the park. The data are intended to provide important baseline information useful in monitoring changes and trends in mammal populations at RICH.

Mammals (except bats) were surveyed in 2003–2004. Stratified (by habitat type) sampling of small to medium-sized mammals relied on the use of Sherman and Tomahawk live traps. Small (< 10 g) shrews were targeted with pitfall traps. Direct observation was used to detect individuals (particularly squirrel-size and larger) and mammal sign helped confirm the identification of individuals of elusive species. Six principal habitat types (field [grasslands, including both managed and old fields], cultivated field, deciduous forest, mixed deciduous-coniferous forest, forested wetland, and wetland) were identified for sampling. Grids and transects of Sherman traps encompassed 1.0 ha (2.5 ac) and 8.0 km (4.9 mi) at 17 locations in 2003 and 1.5 ha (3.7 ac) and 4.4 km (2.7 mi) at 22 locations in 2004. Data were analyzed for species distributions and relative abundances, and species diversity by habitat type. Habitat, mammal captures, and observation data were stored in an electronic (MS Access) database. Voucher specimens were prepared and accessioned into the mammal museum at Frostburg State University.

Our survey resulted in 22 species of mammals either captured or observed within RICH. These species represent six orders and 13 families of mammals. We documented the presence of 58% (22 of 38) of the species (excluding bats) that possibly could occur and 90% (9 of 10) of those for which historical records exist. The survey resulted in 13 new species records for RICH. The white-footed deermouse (*Peromyscus leucopus*) was the most abundant and widely distributed mammal in the park. It was captured in Sherman traps in four (deciduous forest, mixed forest, forested wetland, and wetland) of the six principal habitat types and was the most abundant small mammal in each of these habitats. The woodland vole (*Microtus pinetorum*) was common in deciduous forest and the southern flying squirrel (*Glaucomys volans*) in mixed forest. The meadow vole (*Microtus pennsylvanicus*) and eastern harvest mouse (*Reithrodontomys humulis*) were captured in low numbers in field habitat. The marsh oryzomys (rice rat - *Oryzomys palustris*) was caught in field, forested wetland, and wetland habitats. The house mouse (*Mus musculus*) was the only small mammal captured in cultivated field. Habitat-specific diversity of small mammals generally was low; it was greatest in forested habitats and lowest in wetlands for those habitat types where at least two species were captured. Small mammal species richness, although generally low, was highest in forested wetland habitat. The Virginia opossum (*Didelphis virginiana*) was widely distributed, being either observed or captured in deciduous forest, mixed forest, and forested wetland habitats. Eastern cottontails (*Sylvilagus floridanus*) and woodchucks (*Marmota monax*) were observed frequently in open, grassy areas and forest-field edge. The eastern gray squirrel (*Sciurus carolinensis*) was observed often in deciduous

forest and field habitats. American beaver (*Castor canadensis*) activity was apparent from sign observed at more than one location. Raccoons (*Procyon lotor*) were observed in deciduous forest and captured in field, deciduous forest, mixed forest, and forested wetland habitats. White-tailed deer (*Odocoileus virginianus*) were observed on a number of occasions in forest, field, and forest-field edge habitat and are presumed to be abundant in the park. Eighteen total specimens of nine species of mammals were collected, prepared, and accessioned into the FSU mammal museum.

RICH supports a predictable assemblage of mammal species, but our survey suggests that species diversity of small mammals is low in the park, attributable to low species richness (especially for shrews) and/or low abundances of species present. Additional inventory and monitoring of mammals should be conducted to determine the status of species detected in low numbers or that may be present but were not documented. Grasslands should be sampled more intensively to determine if American least shrews (*Cryptotis parva*) and meadow jumping mice (*Zapus hudsonius*) are present. Marsh habitat and riparian zones should be monitored for the star-nosed mole (*Condylura cristata*), common muskrat (*Ondatra zibethicus*), and North American river otter (*Lontra canadensis*). Transects should be walked and Tomahawk traps used more extensively in deciduous and mixed forests to determine if the eastern fox squirrel (*Sciurus niger*) is a resident of the park. Similarly, increased sampling effort with small Tomahawk traps should be undertaken in forested and field habitats and should be directed to establish the status of the long-tailed weasel (*Mustela frenata*). Pitfall traps should be used in search of small shrew species in all habitats, including fields and wetlands. Conservation of wetlands, careful management of fields, and conservation of conifers, all important to the maintenance of mammalian species diversity, should receive priority in the management of the park's natural resources. The raccoon and white-tailed deer populations in RICH should be monitored periodically to ensure that risks they might pose to intact ecosystems and public health (i.e., rabies, Lyme disease, and Southern Tick-Associated Rash Illness) can be avoided by informed management decisions.

Executive Summary

A survey of mammals (bats excluded) at Richmond National Battlefield Park (RICH) was conducted from 2003 to 2004 to document the presence of $\geq 90\%$ of the mammals in the park, describe their distributions and relative abundances, quantify habitat-specific species diversity, and provide recommendations for management and conservation. Surveys relied on live trapping with Sherman, Tomahawk, and pitfall traps for small to medium-size mammals and direct observation of individuals and their sign (tracks, scats, and recovery of remains). We identified six principal habitats (grasslands [including both managed and old fields], cultivated field, deciduous forest, mixed deciduous-coniferous forest, forested wetland, and wetland) for sampling.

Twenty-two species of mammals were either captured or observed within RICH. Altogether, six orders and 13 families of mammals are represented by these species. We documented 58% (22 of 38) of the species that possibly could occur and 90% (9 of 10) of those for which historical records exist. Our survey resulted in 13 new species records for RICH. The white-footed deermouse (*Peromyscus leucopus*) was the most abundant and widely distributed mammal in the park, occurring in all three forested habitat types and wetland habitat. The woodland vole (*Microtus pinetorum*) was common in deciduous forest and the southern flying squirrel (*Glaucomys volans*) in mixed forest. The meadow vole (*Microtus pennsylvanicus*), eastern harvest mouse (*Reithrodontomys humulis*), and marsh oryzomys (rice rat - *Oryzomys palustris*) were captured in field habitat, and the marsh oryzomys also was caught in forested wetland and wetland habitats. The house mouse (*Mus musculus*) was the only small mammal captured in cultivated field. Habitat-specific diversity of small mammals generally was low; it was greatest in forested habitats and lowest in wetlands for those habitat types where at least two species were captured. Small mammal species richness was highest in forested wetland habitat. Larger habitat generalists that are common in the park include the eastern cottontail (*Sylvilagus floridanus*), woodchuck (*Marmota monax*), eastern gray squirrel (*Sciurus carolinensis*), raccoon (*Procyon lotor*), and white-tailed deer (*Odocoileus virginianus*).

RICH supports a predictable assemblage of mammal species, but our survey suggests that species diversity of small mammals is low in the park, attributable to low species richness (especially for shrews) and/or low abundances of species present. The white-footed deermouse and southern flying squirrel are abundant. Larger habitat generalists, such as the Virginia opossum (*Didelphis virginiana*), eastern cottontail (*Sylvilagus floridanus*), white-footed deermouse, eastern gray squirrel (*Sciurus carolinensis*), raccoon (*Procyon lotor*), and white-tailed deer (*Odocoileus virginianus*), are widely distributed. Also, American beaver (*Castor canadensis*) sign is conspicuous. Adequate quality and quantity of habitat exist to sustain forest-dwelling species.

Additional inventory and monitoring work should be conducted to determine the status of a number of species that were either detected in low numbers – for example, the northern short-tailed shrew (*Blarina brevicauda*), meadow vole (*Microtus pennsylvanicus*), marsh oryzomys (*Oryzomys palustris*), eastern harvest mouse (*Reithrodontomys humulis*), and meadow jumping mouse (*Zapus hudsonius*) – or are suspected of being present but were not detected – for example, the American least shrew (*Cryptotis parva*), southeastern shrew (*Sorex longirostris*),

star-nosed mole (*Condylura cristata*), common muskrat (*Ondatra zibethicus*), eastern fox squirrel (*Sciurus niger*), bobcat (*Lynx rufus*), North American river otter (*Lontra canadensis*), and long-tailed weasel (*Mustela frenata*). This work would focus on additional sampling of grasslands, wetlands, and riparian zones. A concerted effort should be directed toward documenting the populations of small shrews in the park with greater use of pitfall traps, but only after proper archeological compliance or oversight has been completed. In addition, the following resource management strategies might be considered, continued, or enhanced:

- 1) affording special consideration for the protection and conservation of the restricted acreage of wetland habitat and its specialized mammal residents, such as the marsh oryzomys; 2) regulating visitor use of specific areas where sensitive species (e.g., the river otter) are [or may be] found; 3) maintaining and expanding diverse herbaceous communities and interrupting succession in managed fields by careful attention to mowing and burning schedules; 4) periodically monitoring cultivated fields for the [exotic] house mouse (*Mus musculus*); 5) using management practices that either reduce the raccoon population or the consequences of human activities that sustain it (e.g., more frequent trash removal in high-traffic areas); and 6) monitoring and, if necessary, using management practices to regulate white-tailed deer populations to ensure the preservation of vegetation communities and understory cover important to mammals and birds. Raccoons, because of rabies, and white-tailed deer, as important hosts of the black-legged (*Ixodes scapularis*) and lonestar (*Amblyomma americanum*) ticks that are vectors of the etiologic agents (*Borrelia* spp.) for Lyme disease and Southern Tick-Associated Rash Illness (STARI), respectively, also are of potential public health significance in a historical park like RICH with high human visitation.

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Avinash Sareen, M.S. student at Frostburg State University (FSU) and co-author of this report, and Michelle Carder and Stephen Dulin, research technicians, under the supervision of the senior author, conducted the bulk of the field work and collected specimens for accessioning into the FSU mammal museum. We thank Kristen Allen, Natural Resources Manager of RICH, for providing information on the park, collection permits, maps, and other materials, and for the time she spent introducing us to the park and discussing the project with us. We are especially grateful to Kristina Callahan for the generation of metadata for the inventory and the production of the map of sampling locations for the report. We are indebted to John Karish, James Comiskey, Beth Johnson, the National Park Service, and Frostburg State University for funding and logistic support.

Introduction

Surveys of mammals in coastal and mid-Atlantic national parks in the Northeast Region is 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 $\geq 80\%$ of all plant and animal species (excluding invertebrates) occurring within a park's boundaries; the stated objective for the mammal survey of the parks is 90%. 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 the proper stewardship of the park.

We conducted a survey of mammals (except bats, order Chiroptera) in Richmond National Battlefield Park (RICH), Virginia, in 2003–2004 (Figure 1). RICH was established in 1936 and is comprised of approximately 584 ha (1,443 ac) with 12 units in and east of Richmond, Virginia, in Hanover, Chesterfield, and Henrico counties (Figure 2).

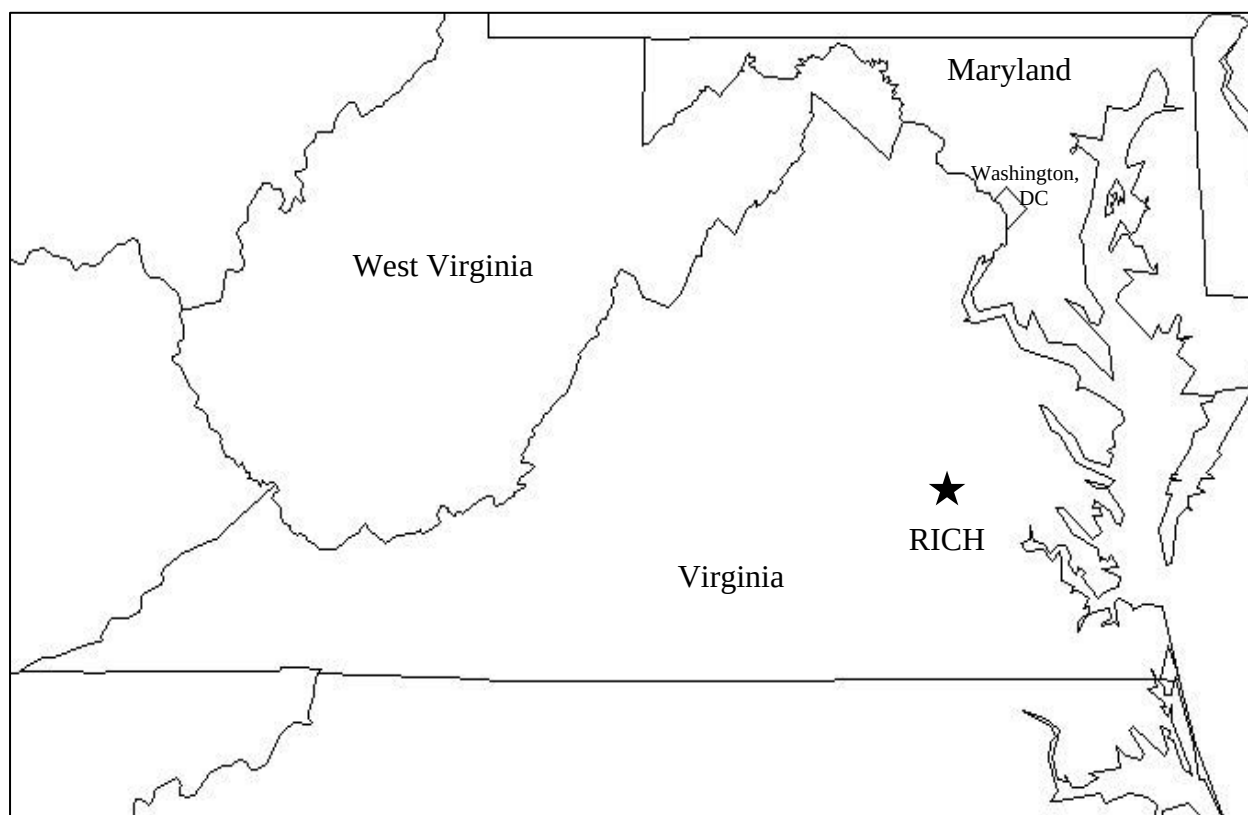


Figure 1. Location of Richmond National Battlefield Park in Virginia. Source of map outline is <http://geography.about.com/library/blank/blxusva.htm>.

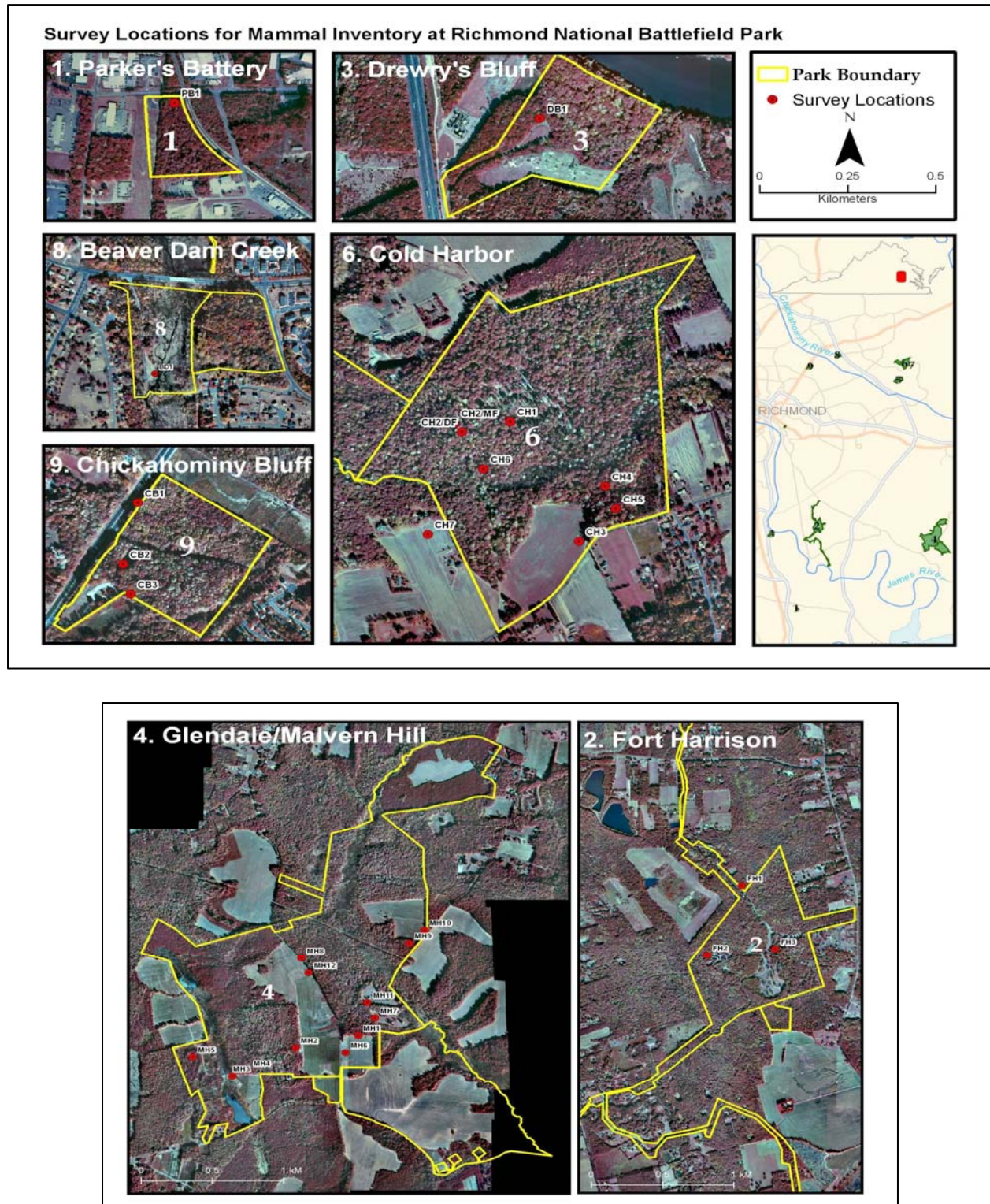


Figure 2. Outline (yellow) of Richmond National Battlefield Park showing locations (red dots) sampled for mammals in 2003 and 2004.

Ten species of mammals are listed on the NPSpecies database for RICH, but no voucher specimens exist (<https://science1.nature.nps.gov/npspecies>). We have uncovered no historical records of other mammal species in the literature or in museums, academic institutions, or park accounts.

Field work began in June 2003 and continued through November 2004. Surveys included sampling of small to medium-size mammals using Sherman and Tomahawk live traps. Small shrews (*Cryptotis parva* and *Sorex* spp.) were targeted with arrays of pitfall kill traps so that individuals could be collected for accurate identification to species by use of skull morphology and dentition. Observations and sign, including tracks, scats and roadkills, were used to account for mammals squirrel-size and larger, beginning in June 2003.

Study Area and Habitats

Richmond National Battlefield consists of 1,019 ha (2,517 ac) (Davis et al. 2006). Approximately 50 ha (124 ac) are leased for agriculture, and another 60 ha (146 ac) are managed fields with bluestem and other native grasses. Wetlands comprise approximately 69 ha (170 ac). The remainder of the park is mostly forested. Forests range from early successional to old growth, from mixed hardwood forests to mixed oaks and mixed deciduous-coniferous forests with pine stands. Dominant woody species include American beech (*Fagus grandifolia*), tulip poplar (*Liriodendron tulipifera*), sweet gum (*Liquidambar styraciflua*), red maple (*Acer rubrum*), oaks (*Quercus* spp.), loblolly pine (*Pinus taeda*), and American holly (*Ilex opaca*). Elevation ranges from approximately 3 m (10 ft) to nearly 42 m (138 ft) (Richmond National Battlefield Park, Kristen Allen, Natural Resources Manager, pers. Comm., 2006).

Delineation of Habitats

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

Six habitat types (field [grasslands, including managed fields and old fields], cultivated field, deciduous forest, mixed deciduous-coniferous forest, forested wetland, and wetland habitats) were identified for inventorying small mammals in RICH. The secure NPSpecies website, <https://science1.nature.nps.gov/npspecies>, lists vascular plants certified for the park.

Fields (FLD)

Common grasses (Poaceae) in fields include broomsedge (*Andropogon virginicus*) and other bluestems (*Andropogon* spp.), fescue (*Festuca* spp.), timothy (*Phleum pratense*), and panic grasses (*Panicum* spp. and/or *Dichanthelium* spp.); more than 90 species of grasses are listed for RICH (see <https://science1.nature.nps.gov/npspecies>). Other common vascular plants in fields include clovers (*Trifolium* spp.), asters (*Aster* spp.), goldenrods (*Solidago* spp.), thistles (*Cirsium* spp.), milkweeds (*Asclepias* spp.), and poison ivy (*Toxicodendron radicans*).

Cultivated Fields (CFLD)

Cultivated fields are planted in corn and soybeans.

Deciduous Forest (DF)

Deciduous forest comprises much of the forested habitat in RICH. Dominant woody species in deciduous forest include oaks (*Quercus* spp., including *Q. velutina* [black]), *Q. phellos* [willow], *Q. falcata* [southern red], and *Q. alba* [white]), American beech, sweetgum, tulip poplar, red maple, pignut hickory (*Carya glabra*), American holly, and blackgum (*Nyssa sylvatica*). Dogwoods (*Cornus* spp.), sassafras (*Sassafras albidum*), blueberries (*Vaccinium* spp.), and brambles (*Rubus* spp.) are common understory and ground species. Greenbriar (*Smilax rotundifolia*) is locally abundant, and the invasive Japanese honeysuckle (*Lonicera japonica*) and

Japanese stiltgrass (*Microstegium vimineum*) are established. Common vines include Virginia creeper (*Parthenocissus quinquefolia*) and poison ivy.

Mixed Deciduous-Coniferous Forest (MF)

Loblolly pine, tulip poplar, and sweetgum are abundant in mixed deciduous-coniferous forest; other pines include Virginia (*P. virginiana*) and shortleaf (*P. echinata*).

Forested Wetlands (FW)

Forested wetlands lie along streams and rivers in deciduous forest. Dominant woody species in this habitat type include sweetgum, red maple, tulip poplar, and sycamore (*Platanus occidentalis*), and a stand of bald cypress (*Taxodium distichum*) at Malvern Hill (Davis et al. 2006).

Wetlands (WL)

Wetlands (swamps and marshes) are restricted in distribution in RICH. Marshes are characterized by a variety of sedges (Cyperaceae), broadleaf arrowhead (*Sagittaria latifolia*), and cutgrass (*Leersia oryzoides*). Woody species in swamps include black willow (*Salix nigra*), loblolly pine, red maple, and ericaceous species (Ericaceae) that include swamp azalea (*Rhododendron viscosum*).

Methods

Sampling Protocol

Sampling sites were located within the six identified habitat types to permit stratified sampling. Habitats initially were identified from aerial photography. Strata were ground-truthed before final selection of sampling sites. The number of sampling locations (sample units) was dependent on 1) number, size, and distribution of habitat types, and 2) constraints imposed by accessibility, equipment, and personnel.

To identify sampling points a systematic grid of UTM coordinates was overlaid on an aerial photograph that depicted habitat types (NPS 2000). 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 Trimble GeoExplorer 3 or comparable GPS unit. Portions of the park frequented by the public, and areas either inaccessible to ground personnel, excluded from sampling by park policy, or logistically impractical to sample with live traps were removed from consideration as sampling locations. Three sampling locations (CB1, FH1, CH7 – see Figure 2) were verified as being just outside park boundaries but were retained as part of the survey because a) the home ranges of individuals at these sites likely traversed park boundaries, and b) the three species captured at these locations were captured elsewhere in the park and, thus, their inclusion did not affect the overall findings of the survey.

Sampling of small mammals relied primarily on capture with rat-sized (7.6×8.9×22.9 cm) Sherman live traps (www.shermantraps.com); 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 target shrews and small mammals < 10 g (Kirkland and Sheppard 1994). Pitfalls for shrews were used as kill-type traps containing 3–5 cm (1.2–5 in) of water because careful measurements and examination of skull morphology and dentition are required for identification of species (Caldwell and Bryan 1982).

Sherman traps were configured at sampling points in randomly positioned linear transects and grids (Table 1; Appendixes A and B), with a trap interval of 10 or 15 m (33 or 50 ft). Trap configuration and number of traps (i.e., grid size or transect length) were dependent on habitat type, patch size, availability of traps, and need for detailed demographic information. 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 2–22 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.

Table 1. Sherman trap configurations and trapping efforts for sampling sites at Richmond National Battlefield Park for 2003 and 2004.

Year	Habitat/Site ¹	Sherman Trap Configuration ²	Trap Nights ³
2003	DF/GM1	Trans (0.75)	500 (30 ^s)
	DF/CH1	Grid (1.00)	2,300 (22 ^m)
	DF/MH1	Trans (0.70)	517
	DF/GM2	Trans (0.34)	253 (22 ^s)
	DF/MH2	Trans (1.02)	612
	WL/MH3	Trans (0.82)	495 (18 ^m)
	DF/MH4	Trans (0.60)	360 (18 ^m)
	DF/MH5	Trans (0.30)	180
	DF/MH6	Trans (0.38)	175 (14 ^m)
	DF/MH7	Trans (0.45)	210 (14 ^m)
	DF/CB1	Trans (0.15)	70
	DF/CB2	Trans (0.30)	140
	WL/CB3	Trans (0.38)	175
	DF/FH1	Trans (0.45)	270
	DF/FH2	Trans (0.45)	270 (18 ^s)
	DF/FH3	Trans (0.30)	180
	DF/CH2	Trans (0.60)	360 (18 ^m)
2004	MF/CH4	Grid (0.25)	2,525 (101 ^m) [276]
	MF/CH3	Trans (0.25)	2,375 (95 ^m) [72]
	MF/CH5	Grid (0.25)	2,225 (89 ^m) [240]
	MF/CH2	Trans (0.25)	1,925 (58 ^m)
	MF/CH6	Trans (0.25)	1,975 (79 ^m) [240]
	MF/CH1	Grid (1.00)	5,200 (104 ^m) [276]
	FWL/BD1	Trans (0.25)	600 (33 ^s , 39 ^m) [66]
	MF/MH8	Trans (0.45)	540 (12 ^m)
	DF/MH9	Trans (0.30)	360 (12 ^m) [72]
	CFLD/MH10	Trans (0.50)	600 (12 ^m)
	DF/MH11	Trans (0.35)	420 (12 ^s) [72]
	DF/FH2	Array	[72]
	OF/MH12	Trans (0.50)	550 (22 ^m)
	OF/GM2	Trans (0.25)	275 (11 ^s)
	FLD/CH7	Trans (0.50)	550 (22 ^m)
	MF/DB1	Trans (0.25)	300 (12 ^m)
	MF/PB1	Trans (0.25)	300 (12 ^m)

¹ CFLD = cultivated field, DF = deciduous forest, FLD = field, FWL = forested wetland, MF = mixed deciduous-coniferous forest, OF = oldfield, WL = wetland. Sites of RICH are identified as BD = Beaver Dam Creek, CB = Chickahominy Bluffs, CH = Cold Harbor, DB = Drewry's Bluff, FH = Fort Harrison, GM = Gaines' Mill, MH = Malvern Hill, PB = Parker's Battery. Number following site is transect or grid number (e.g., GM1 is transect 1 at Gaines Mill).

² Numbers in parentheses for Sherman trap configuration represent effective sampling areas in ha for grids and effective sampling lengths in km for transects. Array = pitfall array only at this site.

³ Trap nights are totals for the habitat/site for Sherman live traps, with trap nights for Tomahawk live traps (^s = small Tomahawk traps, ^m = medium Tomahawk traps – see Methods) in parentheses and pitfall arrays in brackets.

Skunk- (small – 15.2 x 15.2 x 48.3 cm) and raccoon-size (medium - 25.4×30.5×81.3 cm) Tomahawk live traps (www.livetraps.com) were used to capture mammals of squirrel size and larger. One to several of these traps were placed in small mammal (Sherman) trapping grids and transects (Appendixes A and B) 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. An array typically consisted of a 10-m (33-ft) length of silt fence with one pitfall trap (#10 vegetable can) at either end and one or two in the middle (three or four traps total). Each array was placed in association with a Sherman trap transect or within a grid and at least 30 m (98 ft) from another array.

Dominant vegetation, percent canopy cover, percent ground cover, degree of disturbance (e.g., primary or secondary forest or plantation), presence of rock piles, and soil type were noted for each sampling site within Sherman live-trap transects and grids (McDiarmid and Wilson 1996; Barry et al. 1999; Boyce 2001). These observations were recorded as baseline habitat information.

Sherman traps were baited with a combination of peanut butter and rolled oats (Beer 1964), and bird seed was added as a source of quickly metabolizable energy. Tomahawk traps usually were baited with canned cat food. Pitfall traps 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. Because 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). Pitfall traps were used as kill traps because meaningful scientific data on shrews (including species identification) requires careful examination of morphology and dentition (see above). Release of live individuals 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 # A2002-01) at Frostburg State University. 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, and deposited in the Frostburg State University (FSU) mammal museum.

Sampling Periods

We used Sherman and small and medium Tomahawk live traps during eight sampling periods (2–11 nights each) from June to August 2003 at RICH (Table 1; Appendix A). Deciduous forest and wetland habitats were sampled for mammals in this time period. Sherman traps were placed in one grid covering 1.0 ha (2.5 ac) and 16 transects along 8.0 km (4.9 mi) at the 17 sampling locations. Sherman trap nights totaled 7,067 and Tomahawk trap nights 174 at RICH in 2003 (Table 1). Direct observations of mammals were recorded during trapping activities.

We used Sherman, small and medium Tomahawk live traps, and pitfall trap arrays during 15 sampling periods (5–22 nights each) from January to November 2004 at RICH (Table 1; Appendix B). Deciduous forest, mixed deciduous-coniferous forest, forested wetland, field (including managed and old fields), and cultivated field habitats were sampled for mammals. Sherman traps were placed in three grids covering 1.5 ha (3.7 ac) and 13 transects along 4.4 km (2.7 mi) at 16 sampling locations. Pitfall trap arrays alone were used at one sampling location. Sherman trap nights totaled 20,720, Tomahawk trap nights 725, and pitfall trap nights 1,386 at RICH in 2004 (Table 1). Direct observations of mammals were recorded during trapping activities.

Compilation and Analysis of Data

Species distributions among habitats were summarized. Marking and recognition of individuals captured in Sherman and pitfall traps permitted estimates of relative abundance (individuals per 100 trap nights), species diversity (Brillouin's H), rarefaction estimates of richness (number of species), and Smith and Wilson's (E_{var}) measure of evenness (distribution of individuals among the species) for small species for principal habitat types. Analyses followed Krebs (1999) and were conducted at Frostburg State University using EcoMeth software (Krebs 2003).

Data on habitat characteristics and all mammals captured or observed were stored in an electronic database (Microsoft Access). Voucher specimens were prepared and accessioned into the mammal museum at Frostburg State University. Color photographs were provided to the Database Manager for the Mid-Atlantic Network of the NPS.

Results

Historical Records and Predicted Species

Ten mammal species currently are listed on the NPSpecies database (<https://science1.nature.nps.gov/npspecies>) for RICH and are based on observations by park personnel and the public. We have uncovered no historical records of other mammal species in the literature or in museums, academic institutions, or park accounts. According to current taxonomy (Wilson and Reeder 2005), four orders and eight families are represented by the 10 species recorded for RICH prior to this report (Table 2). Based on geographic distributions and habitat preferences, species predicted to occur (possibly occurring) in RICH (Table 2) include 38 species within six orders and 15 families of mammals (excluding bats).

Field Survey

Our survey of 2003–2004 resulted in 22 species of mammals (13 new species records) either captured or observed within RICH (Table 2). These species belong to six orders and 13 families of mammals. In 2003 a total of 190 individuals representing nine species of mammals were captured a total of 469 times at 17 sampling locations (Appendix C). In 2004 at least 214 individuals representing 12 species of mammals were captured a total of 635 times at 14 sampling locations (Appendix D); no mammals were captured in pitfall traps.

The most abundant and widely distributed small mammal in RICH was the white-footed deer mouse (*Peromyscus leucopus*). This species was captured in Sherman traps in four of the six principal habitats sampled (i.e., all except field and cultivated field habitats) and was the most abundant species in those habitat types (forests and wetlands) where it was captured (Table 3).

The woodland vole (*Microtus pinetorum*) was established in deciduous woodland and the southern flying squirrel (*Glaucomys volans*) in mixed deciduous-coniferous forest. The house mouse was the only small mammal captured in cultivated field habitat. Other species were captured infrequently, including the usually widely distributed and abundant northern short-tailed shrew.

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. Six species were captured in Tomahawk traps (see Appendixes C and D). The Virginia opossum (*Didelphis virginiana*) was captured in mixed forest and forested wetland. The gray squirrel (*Sciurus carolinensis*) was caught in mixed forest. A striped skunk (*Mephitis mephitis*) and gray fox (*Urocyon cinereoargenteus*) were trapped in deciduous forest. A domestic cat (*Felis catus*) was captured in forested wetland. A number of raccoons (*Procyon lotor*) were trapped in forested areas (deciduous forest, mixed forest, and forested wetland), and one was caught in a field.

Eleven species of mammals were documented based on observation, sign, or the recovery of remains (Table 4). Nine species were observed directly. Sign or remains of seven species were found. The opossum (*Didelphis virginiana*) was observed in deciduous forest at Malvern Hill. An eastern mole (*Scalopus aquaticus*) was recovered from the side of a gravel road at

Table 2. Comparison of species of mammals predicted to occur in Richmond National Battlefield Park (Gap Analysis¹; Webster et al. 1985; and Linzey 1998), species for which historical records exist (the NPSpecies database²), and species observed during this study (2003–2004). Taxonomy and common names follow Wilson and Reeder (2005).

Order	Family	Species	Common Name	Predicted	Historical	Observed
Didelphimorphia	Didelphidae	<i>Didelphis virginiana</i>	Virginia opossum	X	X	X
Soricomorpha	Soricidae	<i>Blarina brevicauda</i>	northern short-tailed shrew	X		X
		<i>Cryptotis parva</i>	North American least shrew	X		X
		<i>Sorex hoyi</i>	American pygmy shrew	X		
		<i>Sorex longirostris</i>	southeastern shrew	X		
	Talpidae	<i>Condylura cristata</i>	star-nosed mole	X		
		<i>Scalopus aquaticus</i>	eastern mole	X		X
Lagomorpha	Leporidae	<i>Sylvilagus floridanus</i>	eastern cottontail	X		X
Rodentia	Castoridae	<i>Castor canadensis</i>	American beaver	X	X	X
	Cricetidae	<i>Microtus pennsylvanicus</i>	meadow vole	X		X
		<i>Microtus pinetorum</i>	woodland vole	X		X
		<i>Ochrotomys nuttalli</i>	golden mouse	X		
		<i>Ondatra zibethicus</i>	common muskrat	X		
		<i>Oryzomys palustris</i>	marsh oryzomys	X		X
		<i>Peromyscus leucopus</i>	white-footed deermouse	X		X
		<i>Reithrodontomys humulis</i>	eastern harvest mouse	X		X
		<i>Sigmodon hispidus</i>	hispid cotton rat	X		
	Muridae	<i>Mus musculus</i>	house mouse	X		X
		<i>Rattus norvegicus</i>	brown rat	X		
	Sciuridae	<i>Glaucomys volans</i>	southern flying squirrel	X	X	X
		<i>Marmota monax</i>	woodchuck	X	X	X
		<i>Sciurus carolinensis</i>	eastern gray squirrel	X		X
		<i>Sciurus niger</i>	eastern fox squirrel	X		
		<i>Tamias striatus</i>	eastern chipmunk	X		X
		<i>Tamiasciurus hudsonicus</i>	red squirrel	X		
		<i>Zapus hudsonius</i>	meadow jumping mouse	X		
	Dipodidae					
Carnivora	Canidae	<i>Canis latrans</i>	coyote	X		
		<i>Canis lupus</i>	domestic dog	X		
		<i>Urocyon cinereoargenteus</i>	gray fox	X	X	X
		<i>Vulpes vulpes</i>	red fox	X	X	X
	Felidae	<i>Felis catus</i>	domestic cat	X		X
		<i>Lynx rufus</i>	bobcat	X		
	Mephitidae	<i>Mephitis mephitis</i>	striped skunk	X	X	X
	Mustelidae	<i>Lontra canadensis</i>	North American river otter	X	X	

Table 2. Comparison of species of mammals predicted to occur in Richmond National Battlefield Park (Gap Analysis¹; Webster et al. 1985; and Linzey 1998), species for which historical records exist (the NPSpecies database²), and species observed during this study (2003–2004). Taxonomy and common names follow Wilson and Reeder (2005) (continued).

Order	Family	Species	Common Name	Predicted	Historical	Observed
Carnivora (cont'd)	Mustelidae (cont'd)	<i>Mustela frenata</i>	long-tailed weasel	X		
		<i>Neovison vison</i>	American mink	X		X
	Procyonidae	<i>Procyon lotor</i>	raccoon	X	X	X
Artiodactyla	Cervidae	<i>Odocoileus virginianus</i>	white-tailed deer	X	X	X

¹ <http://gapmap.nbii.gov/generatemap.php?species=GENUS%SPECIES&statelist=VA>

² <https://science1.nature.nps.gov/npspecies>

Table 3. Summary of numbers and relative abundances¹ of small mammals captured with Sherman traps in six principal habitat types² at Richmond National Battlefield Park, 2003–2004.

Common name	Scientific name	Habitat type					
		FLD	CFLD	DF	MF	FWL	WL
northern short-tailed shrew	<i>Blarina brevicauda</i>	0(0.00)	0(0.00)	3(0.04)	1(0.01)	0(0.00)	1(0.15)
meadow vole	<i>Microtus pennsylvanicus</i>	1(0.07)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)
woodland vole	<i>Microtus pinetorum</i>	0(0.00)	0(0.00)	13(0.18)	4(0.02)	1(0.15)	0(0.00)
marsh oryzomys	<i>Oryzomys palustris</i>	4(0.29)	0(0.00)	0(0.00)	0(0.00)	1(0.15)	2(0.30)
white-footed deermouse	<i>Peromyscus leucopus</i>	0(0.00)	0(0.00)	142(1.92)	130(0.70)	13(1.95)	28(4.18)
eastern harvest mouse	<i>Reithrodontomys humulis</i>	2(0.15)	0(0.00)	2(0.03)	0(0.00)	0(0.00)	0(0.00)
house mouse	<i>Mus musculus</i>	0(0.00)	6(1.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)
southern flying squirrel	<i>Glaucomys volans</i>	0(0.00)	0(0.00)	0(0.00)	20(0.11)	1(0.15)	0(0.00)
eastern chipmunk	<i>Tamias striatus</i>	0(0.00)	0(0.00)	5(0.07)	7(0.04)	1(0.15)	0(0.00)
Total number of trap nights		1,375	600	7,393	18,469	666	670

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

² Habitat type:

FLD = field (including managed and old fields)

DF = deciduous forest

FWL = forested wetland

CFLD = cultivated field

MF = mixed [deciduous-coniferous] forest

WL = wetland.

Table 4. Mammal sightings or sign in Richmond National Battlefield Park, 2003–2004.

Common name	Scientific name	Means of Observation ¹
Virginia opossum	<i>Didelphis virginiana</i>	✓
eastern mole	<i>Scalopus aquaticus</i>	✓☑
eastern cottontail	<i>Sylvilagus floridanus</i>	✓
American beaver	<i>Castor canadensis</i>	☑
eastern gray squirrel	<i>Sciurus carolinensis</i>	✓☑
woodchuck	<i>Marmota monax</i>	✓☑
red fox	<i>Vulpes vulpes</i>	✓
domestic cat	<i>Felis catus</i>	✓
mink	<i>Neovison vison</i>	☑
raccoon	<i>Procyon lotor</i>	✓☑
white-tailed deer	<i>Odocoileus virginianus</i>	✓☑

¹Means of observation: ✓ Direct observation; ☑ Identified from sign or recovery of remains.

Chickahominy Bluffs where other sign of this species was apparent. Eastern cottontails (*Sylvilagus floridanus*) were observed frequently in grassy areas of the park. Beaver activity was apparent at Gaines' Mill and also at Malvern Hill. Eastern gray squirrels were seen in deciduous forest and field habitat at Gaines' Mill, Fort Harrison, Beaver Dam Creek, and Malvern Hill, and one carcass was recovered as a roadkill from the side of a gravel road at Cold Harbor. The skull of a woodchuck (*Marmota monax*) was found in leaf litter within deciduous forest at Malvern Hill, although live individuals were observed in fields or field-forest edge. Mink (*Neovison vison*) was observed at Chickahominy Bluffs, and a carcass was recovered from the edge of a gravel road at this site. Raccoons were observed in forest habitats, and one was found dead near a roadside pond at Malvern Hill. White-tailed deer (*Odocoileus virginianus*) were observed frequently in forested and field habitats and along forest-field edges.

Species Diversity

Species diversity (Brillouin's *H*) of small mammals captured with Sherman traps was similar in the field and three forest habitat types - deciduous forest, mixed deciduous-coniferous forest, and forested wetland (Table 5). In forested and wetland habitats the white-footed deermouse was numerically dominant. Only one species, the house mouse, was captured in cultivated field habitat.

Evenness was greatest in field habitat where three species were represented among the seven individuals captured (Table 5). Evenness was low in other habitats where the white-footed deermouse was dominant. At a sample size of 17 individuals as a basis for comparison of richness among habitats (to account for differences in sample sizes), the rarefaction estimate of expected number of species was greatest for forested wetland (Figure 3). Too few individuals (<10) were obtained in field and cultivated field habitats for reliable estimates of richness to be made for these habitat types.

Table 5. Brillouin diversity index (determined using $\log_2$) and Smith and Wilson's measure of evenness (Krebs 1999) for small mammals captured in six habitats in Richmond National Battlefield Park, 2003–2004.

Habitat	Brillouin Index (H)	Smith and Wilson's Evenness (E_{var})
Field ¹	0.959	0.803
Cultivated field ¹	*	*
Deciduous forest	0.752	0.260
Mixed forest	0.939	0.229
Forested wetland	0.930	0.484
Wetlands	0.443	0.288

* Only 1 species was captured

¹ Sample size ≤ 10 individuals

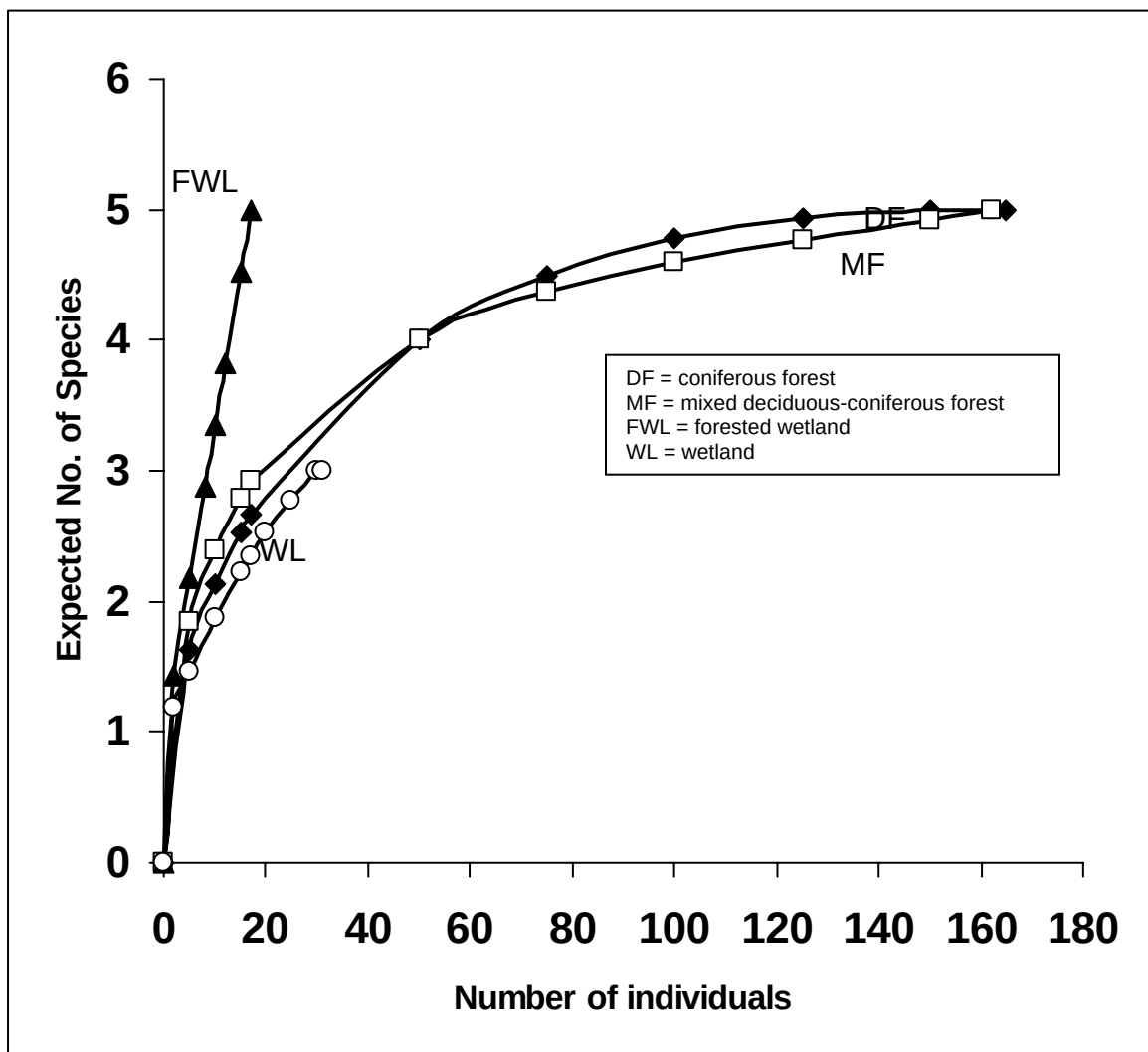


Figure 3. Rarefaction curves showing the estimated number of species of small mammals for variable sample sizes (number of individuals) for four habitat types in Richmond National Battlefield Park.

Voucher Specimens

Eighteen specimens of nine species were collected from RICH in 2003–2004, prepared, assigned FSU catalog numbers, and accessioned into the FSU mammal museum in 2007 (Table 6). All specimens were whole-body liquid preservations. Multiple preparations were made of the northern short-tailed shrew, woodland vole, white-footed deermouse, southern flying squirrel, and eastern chipmunk.

Table 6. Specimens collected in Richmond National Battlefield Park that were assigned catalog numbers and accessioned into the FSU mammal collection (museum) in 2007.

Species	Scientific name	Sex ¹	Specimen Type ²	FSU Catalog Number
northern short-tailed shrew	<i>Blarina brevicauda</i>	M	Li	2937
		F	Li	2938
meadow vole	<i>Microtus pennsylvanicus</i>	M	Li	2933
woodland vole	<i>Microtus pinetorum</i>	F	Li	2924
		F	Li	2935
marsh oryzomys	<i>Oryzomys palustris</i>	M	Li	2934
white-footed deermouse	<i>Peromyscus leucopus</i>	M	Li	2923
		M	Li	2925
		F	Li	2926
		M	Li	2927
		F	Li	2928
		M	Li	2936
eastern harvest mouse	<i>Reithrodontomys humulis</i>	M	Li	2936
house mouse	<i>Mus musculus</i>	F	Li	2922
southern flying squirrel	<i>Glaucomys volans</i>	M	Li	2929
		M	Li	2930
		F	Li	2931
		M	Li	2932
eastern chipmunk	<i>Tamias striatus</i>	M	Li	2932
		F	Li	2939

¹ M = male, F = female

² Li = whole-body liquid preservation

Discussion

Species Records and Predicted Occurrences

We have documented the presence in RICH of 58% (22 of 38) of the nonchiropteran species of mammals that possibly could occur and 90% (9 of 10) of the species for which a historical record exists and that are listed in the NPSpecies database. We were not able to confirm by capture or observation the presence of the North American river otter (*Lontra canadensis*) that is listed on the NPS web site (see above), although this species likely occurs in the park. It occupies permanent watersheds within its range and is often associated with beavers or beaver lodges in bodies of water with banked shores (Lariviere and Walton 1998). Beaver activity has been apparent in the park, which has approximately 6.6 km (11 mi) of rivers and streams.

We were not able to confirm by capture or observation the presence of the following additional species that possibly could reside within RICH: North American least shrew (*Cryptotis parva*), American pygmy shrew (*Sorex hoyi*), southeastern shrew (*Sorex longirostris*), star-nosed mole (*Condylura cristata*), golden mouse (*Ochrotomys nuttalli*), common muskrat (*Ondatra zibethicus*), hispid cotton rat (*Sigmodon hispidus*), brown rat (*Rattus norvegicus*), eastern fox squirrel (*Sciurus niger*), red squirrel (*Tamiasciurus hudsonicus*), meadow jumping mouse (*Zapus hudsonius*), coyote (*Canis latrans*), domestic dog (*Canis lupus*), bobcat (*Lynx rufus*), and long-tailed weasel (*Mustela frenata*). Least, pygmy, and southeastern shrews were not found despite a concerted effort (1,386 trap nights in nine sampling locations) to document these small species with the use of pitfall traps in deciduous and mixed forest habitats and forested wetland (see Appendix B). The least shrew may not have been captured because it is a grassland specialist (Whitaker and Mumford 1972; Whitaker 1974; Linzey 1998), and pitfall traps were not used in this habitat type. Nevertheless, Barry et al. (2008) captured this species with Sherman traps in Fredericksburg and Spotsylvania National Military Park (FRSP). If present in RICH, this species presumably is scarce. The diminutive pygmy shrew often is found in boreal habitats and in or near wetlands (Long 1974). The southeastern shrew is a habitat generalist 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). Suitable (albeit limited) habitat for these three shrew species may exist in RICH, but if present, they likely are scarce based on our failure to capture them. The star-nosed mole is associated with marshland and riparian habitat (Petersen and Yates 1980) and likely resides in RICH. Our failure to detect it may be attributable to the difficulty of detecting sign associated with low species abundance.

The golden mouse and hispid cotton rat may not reside in RICH. The park is at the northeastern extreme of the ranges (Webster et al. 1985; Linzey 1998) of these mammals. The golden mouse prefers areas of thick undergrowth in the form of bushes and vines such as greenbrier and honeysuckle (Linzey and Packard 1977). The cotton rat is a grassland specialist (Cameron and Spencer 1981). The muskrat likely resides in RICH, where suitable habitat exists. Muskrats occupy most aquatic habitats within their North American range, including creeks, lakes, marshes, and ponds (Willner et al. 1980). The brown rat is usually found in association with human habitations (Linzey 1998). We did not sample in or around park buildings. It is possible that the brown rat exists, at least seasonally, at such locations within park boundaries.

The eastern fox squirrel occupies deciduous and mixed-forest habitats with mast-producing oaks, hickories, and pines (Koprowski 1994a) and therefore should reside in the forests of RICH. Future observations targeted for this species likely will confirm its existence. However, the red squirrel is likely absent from RICH. Its distribution in Virginia is disjunct, and it is abundant only in western and northern portions of the state (Linzey 1998; Steele 1998). Also, RICH lacks the preferred habitat of this species, boreal coniferous forest (Steele 1998). The meadow jumping mouse likely resides in RICH, although it may not be abundant, as its absence from our survey suggests. This species is a grassland specialist, although it occupies a variety of habitats besides fields, including thickly vegetated edges of ponds, streams, and swamps (Whitaker 1972).

No coyote was observed in RICH in 2003–2004. Although this species may not be a permanent resident of the park, it may exist as a transient because individuals occupy a wide diversity of habitats and exhibit extensive movements (Beckoff 1977). Domestic dogs, although not observed in our sample, likely stray into the park from neighboring residential properties. Although no bobcats or their sign were observed in RICH, suitable habitats and prey (lagomorphs, voles, sciurids, and larger rodents) are present (Lariviere and Walton 1997) to support this species. The long-tailed weasel is a generalist predator that feeds on a wide variety of prey, but especially small to medium-size rodents and rabbits (Sheffield and Thomas 1997). It occupies a wide variety of habitats but is at least partially restricted to areas close to water. It is likely a resident of RICH, although not abundant, as our failure to capture any individuals would suggest.

Habitat Generalists

The white-footed deermouse is a woodland species that occurs statewide (Linzey 1998). It occurred in four of the six principal habitat types in RICH, being absent only from managed and cultivated fields. It is found most commonly in brushy habitat or wooded areas dominated by deciduous species and ample, downed woody debris (Barry and Francq 1980; Lackey et al. 1985), but it also is known to occur in fields. The northern short-tailed shrew occurs within a wide variety of habitats throughout its range (George et al. 1986) and was found in three of the six habitats sampled in RICH. It was not captured in fields, although grassland habitat is often occupied by this species where it coexists and often preys on the meadow vole. Our failure to capture this shrew in fields may relate to the scarcity of meadow voles in the fields we sampled. The woodland vole was captured in all three types of forested habitat in RICH. It can be found in deciduous forests, grasslands, among shrubs, and in orchards – anywhere where ground cover in the form of litter or vegetation is abundant (Miller and Getz 1969; Smolen 1981).

Eastern cottontails and woodchucks were observed frequently in open, grassy areas and forest-field edges in RICH. 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). Woodchucks typically occupy field-forest ecotone (Kwiecinski 1998).

Eastern gray squirrels use a variety of habitats throughout their range (Koprowski 1994b; Linzey 1998; Edwards et al. 2003) but are most common in mature, intact deciduous and mixed deciduous-coniferous woodlands. We observed them in both deciduous forest and field habitats

in RICH. The raccoon and Virginia opossum exhibit a wide breadth of habitat use (McManus 1974; Lotze and Anderson 1979; Gardner and Sunkist 2003; Gehrt 2003). Both species were observed in deciduous woodland in the park. Opossums also were captured in mixed forest and forested wetland, and raccoons were trapped in a field and all three forested habitat types. Extensive forest acreage provides ample opportunity for these two habitat generalists.

Both the gray and red fox were documented by our survey. Both species traverse a variety of habitats within their considerable home ranges. Gray foxes are more often associated with woodlands and red foxes with fragmented landscapes, but gray foxes in eastern North America prefer a mix of fields and forest (Cypher 2003). The gray fox we captured was taken in deciduous woodland. RICH provides ample suitable habitat for these canids.

Striped skunks occupy both field and forest habitat. We captured one individual in deciduous forest but did not observe any individuals during our sampling—surprising considering the ubiquity of this species and abundance of suitable habitat in RICH. Similarly, Barry et al. (2008) had few encounters with this species in FRSP in 2004–2005. Wade-Smith and Verts (1982) described the large density fluctuations typical of this species in some areas. Abundance in RICH in 2003–2004 could have been low. This, in combination with the frequent movement of individuals to locations where they can forage optimally on insects, notably beetles (Rosatte and Lariviere 2003), could explain the paucity of encounters. We suspect that skunks are distributed widely in RICH, as elsewhere within their range.

White-tailed deer occupy both open and forested habitats (Miller et al. 2003) but are most often associated with woodlands (Linzey 1998). We observed them in forest, field, and forest-field edge habitat. They appear to be abundant in RICH.

Habitat Specialists

Several of the small mammal species represented in our survey can be considered grassland or field specialists. The eastern mole can be found in meadows, gardens, cultivated fields, forests, and river bottoms (Linzey 1998). Yates and Schmidly (1978) reported that the eastern mole avoids clay and gravel, but the individual we recovered was found along the side of a gravel road. The meadow vole and eastern harvest mouse were captured in RICH fields. We captured only one meadow vole. This species is typically abundant in eastern open grasslands, but populations can undergo multiannual fluctuations (Reich 1981; Linzey 1998; Getz et al. 2001). Low capture frequency also could be related to the restricted time period during which fields were sampled. The eastern harvest mouse has been found primarily in old fields (Stalling 1997) containing plants such as broomsedge (*Andropogon* spp.) and goldenrod (*Solidago* spp.), two taxa prominent in RICH fields. In our survey, two individuals also were captured in deciduous forest, although they likely were residents of adjacent grassland.

The eastern chipmunk was captured in a variety of RICH forest habitats. The preferred habitat of this species is deciduous forest, especially where crevices are abundant that serve as refuges (Snyder 1982). The southern flying squirrel was abundant in mixed forest, consistent with previous reports of its preference for mature hardwood or mixed deciduous-coniferous forests in Virginia (Linzey 1998).

We captured marsh oryzomys in field, forested wetland, and wetland habitats. This mammal is semiaquatic and found mostly in wetlands (Wolfe 1982).

Beaver sign was observed at more than one location in RICH. Beavers typically are associated with flowing water or other habitats that permit dam construction (Linzey 1998). Availability of food is an important factor in the suitability of a habitat for beavers (Jenkins and Busher 1979), and wooded habitat in RICH apparently provided adequate food resources (e.g., *Salix* spp. [willow]) at the time of occupancy.

We observed a mink and recovered a carcass of this mammal within RICH. Minks are usually found near water (Lariviere 1999) and may seek permanent wetlands as dry seasons approach (Humphrey and Zinn 1982). The American mink is likely an established resident of RICH.

Exotic Species

A number of house mice were captured in a cultivated field within the park. The house mouse is commonly the most abundant mammal in such habitat in Virginia (Linzey 1998). Although no domestic dogs were observed during our sampling activities, a domestic cat was captured. This individual could have been feral or from a neighboring residential neighborhood.

Habitat-specific Species Diversity

Species diversity of small mammals at RICH was greatest in forested habitats. Five species of small mammals were caught in both deciduous and mixed deciduous-coniferous forests and also in forested wetlands. However, sampling effort in deciduous and mixed forest habitats far exceeded those in other habitat types. The emphasis on sampling in these habitats related not only to the large proportion of total area in RICH comprised by these habitat types but also to the areas available for sampling and the M.S. research project conducted by the junior author of this report, whose research focused on forested habitat. Rarefaction estimates showed that when sample size was standardized at 17 individuals (the size of the smallest sample in the four principal habitat types that yielded more than one species and 10 individuals), forested wetlands exhibited the greatest species richness. The estimate of evenness was comparatively great for field habitat, but little confidence is associated with this estimate because total captures in fields were so low. Evenness estimates for other habitat types was very low because of the dominance of the white-footed deermouse in each.

All forest habitat types supported a high relative abundance of the white-footed deermouse. This species was most abundant in deciduous forest, its preferred habitat (Lackey et al. 1985). The only other small mammals that were reasonably abundant in forests were the woodland vole in deciduous forest and southern flying squirrel in mixed forest habitat. The woodland vole is cosmopolitan in its choice of habitats, as long as ground cover is abundant (Miller and Getz 1969; Smolen 1981). Mixed forest is a preferred habitat of the southern flying squirrel (Linzey 1998). Comparatively high species diversity indices for forested habitats were attributable to both species richness and high abundance of the white-footed deermouse.

Sampling Efficiency

Sherman traps are the industry standard for live capture of rodents and shrews of body mass ≥ 10 g (Mitchell et al. 1993) and were used with success to capture a number of species in a variety of habitats. However, for smaller species pitfall traps have been found to be more efficient (Szaro et al. 1988; Kirkland and Sheppard 1994; Umetsu et al. 2006; Sedivec and Whidden 2007). This was not the case for our survey. We captured no individuals in pitfall traps despite 1,386 trap nights of effort. We limited the use of these traps to forested habitat (including forested wetland) specifically to target small shrews that cannot be captured by any other means. However, a disproportionate number of pitfall trap nights was realized during the winter and early spring months (approximately 80% during these periods combined, 60% in winter alone) when surface activity of shrews may have been limited. It is likely that the American least shrew would have been captured in field habitat had pitfall traps been used. However, the placement of pitfall traps is labor-intensive, and their use often imposes unacceptable risks (see *Additional Inventories* below).

We had considerable success with Tomahawk traps. We captured six species of mammals in these traps, mostly in forested habitats where they were used most extensively. Direct observation, especially while conducting trap sampling, is efficient for detecting sign and medium to large, nonsecretive species. In RICH we observed 11 species of mammals by some combination of direct observation of individuals, sign, or recovery of remains.

Conclusions and Management Recommendations

Our survey of mammals of the park addresses one of the five long-term goals established by the Natural Resource Inventory and Monitoring Program of the National Park Service (NPS 1998) for the mid-Atlantic parks of the Northeast region: to complete baseline inventories of basic biological and geophysical natural resources. Our inventory of the mammals of RICH documents the presence of particular species of mammals, notes their habitat associations, describes sampling protocol, and provides information that can be used to monitor mammal populations, and herein provides recommendations for their conservation and management.

The outcome of our survey effort at RICH suggests that diversity and abundances of small mammals are low in the park. Apart from the white-footed deermouse, woodland vole, and southern flying squirrel, small mammals are characterized by low relative abundances. The white-footed deermouse predictably is abundant in wooded habitats and somewhat surprisingly so in wetlands. However, relative abundance of the generally common northern short-tailed shrew is low in forest habitats and this generalist species was not captured in grassland. This was the only shrew species that was captured despite a considerable sampling effort with pitfall traps targeted for shrew species in forest and forested wetland habitats. Additional sampling with pitfall traps should be conducted in an attempt to confirm the status of shrew species. The meadow vole, usually abundant in grassland, was scarce in our sample of this habitat type, which may explain, in part, our failure to detect the long-tailed weasel. Generally, common larger species, such as the eastern cottontail rabbit, eastern gray squirrels woodchuck, Virginia opossum, raccoon, and white-tailed deer, were trapped or observed frequently in their preferred habitats. Special attention should be paid to the management of grassland habitats for small mammal populations such as the meadow vole, eastern harvest mouse, and meadow jumping mouse.

Several species present in RICH are specialists dependent on wetland and/or riparian habitats. The semiaquatic marsh oryzomys was found (but not abundant) in forested wetland and wetland habitat. Beavers occupy (or occupied) riparian areas within forested habitats of RICH. Of concern was our failure to observe muskrats and river otters, both of which depend on wetland and riparian habitats. It is extremely important that careful attention be paid to the protection and maintenance of such areas to sustain existing populations and, potentially, increase the diversity of wetland species in the park.

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., northern short-tailed shrew, meadow vole, and eastern harvest mouse) or could not confirm but that may be present because RICH is within their ranges and contains what appears to be suitable habitat (e.g., American least shrew, star-nosed mole, common muskrat, meadow jumping mouse, eastern fox squirrel, North American river otter, and long-tailed weasel). Additional locations in fields should be sampled to determine if least shrews and meadow jumping mice are present. Marsh habitat and riparian zones should be monitored for sign of the star-nosed mole (Petersen and Yates 1980), muskrat, and river otter; harpoon traps could be used in an attempt to capture the star-nosed mole in such

habitats. Transects should be walked and Tomahawk traps used more extensively in deciduous and mixed forests to establish the presence/absence of the eastern fox squirrel, which typically occurs in oak and pine stands (Koprowski 1994a). Increased sampling effort with small Tomahawk traps in forested and field habitats should be directed toward establishing the status of the long-tailed weasel. This species is a habitat and food habits generalist (Sheffield and Thomas 1997) that should be present in RICH.

We used pitfall trap arrays only in forested and forested wetland habitats. The use of pitfall traps should be extended to additional habitats to establish the presence and statuses of small shrew species. However, 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. Further, pitfall traps in frequently visited and/or heavily used areas of the park may pose a public safety issue.

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. RICH wetlands and wooded riparian zones provide critical habitat for such mammals as the marsh oryzomys and beaver and perhaps other species not detected but present in low abundance (e.g., the muskrat and river otter); such habitat should receive special consideration for conservation efforts.

Fields should be maintained and managed carefully to retain and restore healthy populations of small mammals, which in turn sustain larger species. Management specifically for such grassland specialists as the American least shrew, meadow vole, eastern harvest mouse, and meadow jumping mouse might also benefit other grassland species. Properly scheduled mowing and prescribed burns can be used to interrupt succession and maintain herbaceous vegetation suitable to the resource requirements of such species as the eastern harvest mouse (Tanner and Kneipp 2007). These and other management practices that enhance low, herbaceous (especially poaceous) ground cover likely would benefit meadow voles (Reich 1981; Getz et al. 2001).

Management in RICH specifically for conifer species should be pursued as a strategy to increase mammal species diversity, especially shrews. Barry et al. (2008) documented three species of shrews and overall high species richness in coniferous forest in FRSP, just north of RICH. Maintenance of mixed deciduous-coniferous and mature (old-growth) deciduous forests (Davis et al. 2006) also is important in sustaining the robust population of the southern flying squirrel.

Species Management

Management for the control of particular mammal species in RICH might be warranted. Based on frequency of captures and encounters, the raccoon appears to be abundant in the park. In numbers it can be a significant predator on bird and reptile eggs and nestlings. It also is the primary terrestrial reservoir of rabies in the Southeast, and raccoon rabies is easily spread to feral cats. Most cases of human exposure to rabies result from contact with cats (Gehrt 2003). Measures (e.g., tamper-proof trash containers and frequent trash removal in heavily trafficked

areas) that would reduce the consequences of human activities that sustain raccoon populations can be intensified to reduce the risks to wildlife and humans of a robust raccoon population.

Management for the control of the white-tailed deer in RICH might be warranted. Frequent sightings and abundant sign are evidence that this species is abundant in the park. Deer in abundance can alter the stable state of a northern temperate forest (Stromayer and Warren 1997) by reducing understory cover important to mammals and birds. Also, deer serve as hosts to a diversity of ectoparasites, including *Ixodes scapularis*, the black-legged tick, and *Amblyomma americanum*, the lonestar tick, that are the vectors of the etiologic agents for Lyme disease (the spirochete, *Borrelia burgdorferi* -- Miller et al. 2003) and Southern Tick-Associated Rash Illness, or STARI (the spirochete, *Borrelia lonestari* – Kollars et al. 2000), respectively. Tanner (2007) found lonestar ticks infected with *B. lonestari* in FRSP, and it is likely that lonestar ticks parasitize deer in RICH. Monitoring the deer population (e.g., with pellet-group counts) and continuing the current activity of monitoring forest understory vegetation and regeneration in the park are recommended. If such screening suggests that deer may be altering the habitat to the detriment of other fauna, management practices to regulate the deer population might be justified.

Populations of RICH mammals we documented should be monitored and efforts to confirm the presence or absence of those species expected to be residents should be continued. Management decisions that can effect proper stewardship of natural systems necessarily rely on periodic assessments of species diversity and abundances from inventory and monitoring activities. Also, the results of our inventory suggest that measures should be taken to augment the populations of small mammals, especially in grassland habitats using methods to interrupt succession (see above). In addition to the impacts of larger species on systems, such as those described earlier, the role of small mammals as critical components of biological communities is well-recognized (e.g., by 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 (Sekgororoane and Dilworth 1995; Carey and Harrington 2001).

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Appendix A. Trapping schedule, habitats, locations, and trapping efforts for 2003 in Richmond National Battlefield Park.

Dates ¹	Ha bitat/Site ²	Location ³	Sherman Trap Configuration ⁴	Trap Nights ⁵
6/3–12	DF/GM1	0297213 4160951	Trans (0.75)	500 (30 ^s)
6/3–12	DF/CH1	0298082 4162886	Grid (1.00)	2,300 (22 ^m)
6/20–30				
7/9–10				
6/20–30	DF/MH1	0301095 4143361	Trans (0.70)	517
6/20–30	DF/GM2	0297755 4161070	Trans (0.34)	253 (22 ^s)
6/22–30	DF/MH2	0306655 4143257	Trans (1.02)	612
7/9–17	WL/MH3	0300212 4143014	Trans (0.82)	495 (18 ^m)
7/9–17	DF/MH4	0300321 4143064	Trans (0.60)	360 (18 ^m)
7/9–17	DF/MH5	0299933 4143177	Trans (0.30)	180
7/24–30	DF/MH6	0301006 4143216	Trans (0.38)	175 (14 ^m)
7/24–30	DF/MH7	0301213 4143511	Trans (0.45)	210 (14 ^m)
7/24–30	DF/CB1	0289086 4162675	Trans (0.15)	70
7/24–30	DF/CB2	0289044 4162475	Trans (0.30)	140
7/24–30	WL/CB3	0289066 4162377	Trans (0.38)	175
8/5–13	DF/FH1	0289846 4145700	Trans (0.45)	270
8/5–13	DF/FH2	0289603 4145104	Trans (0.45)	270 (18 ^s)
8/5–13	DF/FH3	0290080 4145159	Trans (0.30)	180
8/5–13	DF/CH2	0297945 4162853	Trans (0.60)	360 (18 ^m)

¹ Dates are nights Sherman traps were open.

² DF = deciduous forest, WL = wetland. Sites are identified as CB = Chickahominy Bluffs, CH = Cold Harbor, FH = Fort Harrison, GM = Gaines' Mill, MH = Malvern Hill.

³ UTM coordinates are for middle of grid or one end of transect; zone 18, NAD 83, meters. See Figure 2 for map of locations.

⁴ Numbers in parentheses for Sherman trap configuration are effective sampling area in ha for grids (Grid) and effective sampling length in km for transects (Trans).

⁵ Total Sherman trap nights (trap interval =15 m, except 10 m in DF/CH1), with Tomahawk (^s = small, ^m = medium – see Methods) trap nights in parentheses.

Appendix B. Trapping schedule, habitats, locations, and trapping efforts for 2004 in Richmond National Battlefield Park.

Dates ¹	Habitat/Site ²	Location ³	Sherman Trap Configuration ⁴	Trap Nights ⁵
1/15–/25	MF/CH4	0298351 4162676	Grid (0.25)	2,525 (101 ^m) [276]
2/7–/11				
2/21–3/13				
3/19–25				
4/16–21				
5/17–22				
6/20–7/1				
7/21–27				
8/4–14				
9/19–24				
11/3–12				
1/15–25	MF/CH3	0298277 4162495	Trans (0.25)	2,375 (95 ^m) [72]
2/7–11				
2/21–3/13				
3/19–25				
4/16–21				
5/17–22				
6/20–7/1				
7/21–27				
8/4–14				
11/3–12				
1/15–25	MF/CH5	0298382 4162602	Grid (0.25)	2,225 (89 ^m) [240]
2/7–11				
2/21–3/13				
3/19–25				
4/16–21				
6/20–7/1				
7/21–27				
8/4–14				
11/3–12				
1/15–25	MF/CH2	0297923 4162881	Trans (0.25)	1,925 (58 ^m)
2/7–11				
2/21–3/13				
3/19–25				
4/16–21				
7/21–27				
8/4–14				
11/3–12				
2/7–11	MF/CH6	0298006 4162732	Trans (0.25)	1,975 (79 ^m) [240]
2/21–13				
3/19–25				
4/16–21				
6/20–7/1				
7/21–27				
8/4–14				
11/3–12				

Appendix B. Trapping schedule, habitats, locations, and trapping efforts for 2004 in Richmond National Battlefield Park (continued).

Dates ¹	Habitat/Site ²	Location ³	Sherman Trap Configuration ⁴	Trap Nights ⁵
4/16–21	MF/CH1	0298082 4162886	Grid (1.00)	5,200 (104 ^m) [276]
6/20–7/1				
7/21–27				
8/4–14				
9/19–24				
11/3–12				
5/29–6/10	FWL/BD1	0291739 4163579	Trans (0.25)	600 (33 ^s , 39 ^m) [66]
8/4–14				
7/10–21	MF/MH8	0300698 4144023	Trans (0.45)	540 (12 ^m)
7/10–21	DF/MH9	0301454 4144152	Trans (0.30)	360 (12 ^m) [72]
7/10–21	CFLD/MH10	0301559 4144263	Trans (0.50)	600 (12 ^m)
7/10–21	DF/MH11	0301160 4143643	Trans (0.35)	420 (12 ^s) [72]
7/10–21	DF/FH2	0289603 4145104		[72]
9/1–11	OF/MH12	0300748 4143897	Trans (0.50)	550 (22 ^m)
9/1–11	OF/GM2	0297738 4160908	Trans (0.25)	275 (11 ^s)
9/1–11	FLD/CH7	0295848 4162518	Trans (0.50)	550 (22 ^m)
10/12–23	MF/DB1	0285473 4144375	Trans (0.25)	300 (12 ^m)
10/12–23	MF/PB1	0287920 4136391	Trans (0.25)	300 (12 ^m)

¹ Dates are nights Sherman traps were open.

² CFLD = cultivated field, DF = deciduous forest, FLD = field, FWL = forested wetland, MF = mixed deciduous-coniferous forest, OF = old field. Sites are identified as BD = Beaver Dam Creek, CH = Cold Harbor, DB = Drewry's Bluff, FH = Fort Harrison, GM = Gaines' Mill, MH = Malvern Hill, PB = Parker's Battery.

³ UTM coordinates are for middle of grid or one end of transect; zone 18, NAD 83, meters. See Figure 2 for map of locations.

⁴ Numbers in parentheses for Sherman trap configuration are effective sampling area in ha for grids (Grid) and effective sampling length in km for transects (Trans).

⁵ Total Sherman trap nights (trap interval = 10 m), with Tomahawk (^s = small, ^m = medium – see Methods) trap nights in parentheses and pitfall trap nights in brackets.

Appendix C. Capture record for mammals caught in Richmond National Battlefield Park from June through August 2003.

Habitat/site ¹	Trap Nights ²	Species ³	No. Individuals	Total Captures	Relative Abundance
DF/GM1	500 (30 ^s)	<i>Peromyscus leucopus</i>	15	23	3.0
		<i>Microtus pinetorum</i>	1	2	0.2
DF/CH1	2300 (22 ^m)	<i>Blarina brevicauda</i>	1	1	0.4
		<i>Peromyscus leucopus</i>	25	42	1.1
		<i>Microtus pinetorum</i>	5	8	0.2
		<i>Tamias striatus</i>	2	2	0.1
		<i>Urocyon cinereoargenteus</i>	1	1	-
		<i>Procyon lotor</i>	3	3	-
DF/MH1	517	<i>Peromyscus leucopus</i>	23	69	4.4
		<i>Microtus pinetorum</i>	6	13	1.2
		<i>Tamias striatus</i>	3	3	0.6
DF/GM2	253 (22 ^s)	<i>Peromyscus leucopus</i>	9	33	3.6
		<i>Procyon lotor</i>	1	1	-
DF/MH2	612	<i>Peromyscus leucopus</i>	20	66	3.3
		<i>Microtus pinetorum</i>	1	1	0.2
WL/MH3	495 (18 ^m)	<i>Blarina brevicauda</i>	1	2	0.2
		<i>Peromyscus leucopus</i>	22	88	4.4
		<i>Oryzomys palustris</i>	2	2	0.4
DF/MH4	360 (18 ^m)	<i>Blarina brevicauda</i>	2	3	0.6
		<i>Peromyscus leucopus</i>	7	20	1.9
DF/MH5	180	<i>Peromyscus leucopus</i>	5	21	2.8
DF/MH6	175 (14 ^m)	<i>Peromyscus leucopus</i>	5	9	2.9
		<i>Reithrodontomys humulis</i>	1	1	0.6
DF/MH7	210 (14 ^m)	<i>Peromyscus leucopus</i>	1	1	0.5
		<i>Reithrodontomys humulis</i>	1	1	0.5
DF/CB1	70	<i>Peromyscus leucopus</i>	2	3	2.9
DF/CB2	140	<i>Peromyscus leucopus</i>	2	5	1.4
WL/CB3	175	<i>Peromyscus leucopus</i>	6	7	3.4
DF/FH1	270	<i>Peromyscus leucopus</i>	5	12	1.9
DF/FH2	270 (18 ^s)	<i>Peromyscus leucopus</i>	8	19	3.0
		<i>Mephitis mephitis</i>	1	1	-
DF/FH3	180	<i>Peromyscus leucopus</i>	1	1	0.6
DF/CH2	360 (18 ^m)	<i>Peromyscus leucopus</i>	2	5	0.6

¹ DF = deciduous forest, WL = wetland. Sites are identified as CB = Chickahominy Bluffs, CH = Cold Harbor, FH = Fort Harrison, GM = Gaines' Mill, MH = Malvern Hill. See Figure 2 and Appendix A for locations of habitat/site.

² Trap Nights = total Sherman trap nights in **bold**, small (s) and medium (m) Tomahawk trap nights in parentheses.

³ See Table 2 for common names.

⁴ Relative abundance is individuals/100 Sherman trap nights. Relative abundances are not determined for captures in Tomahawk traps.

Appendix D. Capture record for mammals caught in Richmond National Battlefield Park from January through November 2004.

Habitat/site ¹	Trap Nights ²	Species ³	No. Individuals	Total Captures	Relative Abundance ⁴
MF/CH4	2,525 (101 ^m) [276]	<i>Peromyscus leucopus</i>	24	94	0.9
		<i>Glaucomys volans</i>	1	1	0.0
		<i>Procyon lotor</i>	1	1	-
MF/CH3	2,375 (95 ^m) [72]	<i>Blarina brevicauda</i>	1	1	0.0
		<i>Microtus pinetorum</i>	1	1	0.0
		<i>Peromyscus leucopus</i>	16	64	0.7
		<i>Glaucomys volans</i>	8	14	0.3
		<i>Sciurus carolinensis</i>	1	1	-
MF/CH5	2,225 (89 ^m) [240]	<i>Peromyscus leucopus</i>	16	92	0.6
		<i>Glaucomys volans</i>	2	2	0.1
		<i>Tamias striatus</i>	1	1	0.0
MF/CH6	1,975 (79 ^m) [240]	<i>Didelphis virginiana</i>	1	1	-
		<i>Peromyscus leucopus</i>	20	82	0.9
		<i>Glaucomys volans</i>	6	13	0.3
		<i>Tamias striatus</i>	2	8	0.1
MF/CH1	5,200 (104 ^m) [276]	<i>Microtus pinetorum</i>	3	12	0.1
		<i>Peromyscus leucopus</i>	46	117	0.8
		<i>Mus musculus</i>	2	2	0.0
		<i>Glaucomys volans</i>	3	3	0.1
		<i>Tamias striatus</i>	4	5	0.1
		<i>Procyon lotor</i>	?	3	-
FWL/BD1	600 (33 ^s ,39 ^m) [66]	<i>Didelphis virginiana</i>	1	1	-
		<i>Microtus pinetorum</i>	1	3	0.2
		<i>Oryzomys palustris</i>	1	1	0.2
		<i>Peromyscus leucopus</i>	13	27	2.0
		<i>Glaucomys volans</i>	1	1	0.2
		<i>Tamias striatus</i>	1	1	0.2
		<i>Procyon lotor</i>	?	2	-
		<i>Felis catus</i>	1	1	-
MF/MH8	540 (12 ^m)	<i>Peromyscus leucopus</i>	5	15	0.9
DF/MH9	360 (12 ^m) [72]	<i>Peromyscus leucopus</i>	4	15	0.9
CFLD/MH10	600 (12 ^m)	<i>Mus musculus</i>	6	16	1.0
DF/MH11	420 (12 ^s) [72]	<i>Peromyscus leucopus</i>	8	23	1.6
OF/MH12	550 (22 ^m)	<i>Microtus pennsylvanicus</i>	1	1	0.2
		<i>Oryzomys palustris</i>	4	4	0.7
		<i>Reithrodontomys humulis</i>	1	1	0.2
FLD/CH7	550 (22 ^m)	<i>Reithrodontomys humulis</i>	1	1	0.2
		<i>Procyon lotor</i>	1	1	-
MF/DB1	300 (12 ^m)	<i>Peromyscus leucopus</i>	1	1	0.3
MF/PB1	300 (12 ^m)	<i>Peromyscus leucopus</i>	2	2	0.7

¹ CFLD = cultivated field, DF = deciduous forest, FLD = field, FWL = forested wetland, MF = mixed deciduous-coniferous forest, OF = old field. Sites are identified as BD = Beaver Dam Creek, CH = Cold Harbor, DB = Drewry's Bluff, FH = Fort Harrison, GM = Gaines' Mill, MH = Malvern Hill, PB = Parker's Battery.

² Trap Nights = total Sherman trap nights in **bold**, small (^s) and medium (^m) Tomahawk trap nights in parentheses, and pitfall trap nights in brackets.

³ See Table 2 for common names.

⁴ Relative abundance is individuals/100 Sherman and pitfall trap nights. Relative abundances are not determined for captures in Tomahawk traps.

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