

Management Plan for a Degraded Meadow Infested with Morrow's Honeysuckle

Results of a Comprehensive Inventory of Flora and Fauna and the
Implications of Management Options on the Ecological Communities
and Historical Landscape at Fort Necessity National Battlefield, PA

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Photos (clockwise from top left): 1) Four types of honeysuckle removal methods were tested, including cutting the shrubs with a chainsaw. 2) Several American woodcock were found in the study area (Photo courtesy Don Riepe, NYC Audubon Society). 3) Smooth green snakes were one of four snake species identified in the study area. 4) Masked shrews were one of several small mammals captured within the study area.

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Managerial Summary

Morrow's honeysuckle (*Lonicera morrowii*) is an invasive exotic shrub that was brought to the United States from Japan circa 1875. Since that time, it has spread from gardens and hedgerows and now can be found in many natural areas in the eastern and mid-western United States. At Fort Necessity National Battlefield, the shrub has invaded both forests and fields, where it out-competes native plants, reducing biodiversity and altering the cultural landscape. On the hillside adjacent to Fort Necessity, the shrubs have formed a monoculture; Morrow's honeysuckle makes up nearly 94% of all woody stems, thereby impeding reforestation and restoration of the site.

We set up experiments to assess the effect of the shrub on small mammals, songbirds, amphibians, reptiles, earthworms, invertebrates, and a declining gamebird, American Woodcock. In addition, we established experimental plots to test methods to control the shrub. The goal of the various studies was to develop a comprehensive management plan that will be used to help guide restoration efforts of honeysuckle-dominated areas.

We identified 11 species of small mammals, 33 species of birds, 6 species of amphibians, 3 species of reptiles, and 4 species of exotic earthworms. We discovered that American Woodcock used the area during spring as singing grounds, but used the area only sporadically during the summer. We also found that Morrow's honeysuckle negatively affects herbivorous insects, since most are not adapted to feed on the leaves. When the shrub forms dense thickets, abundance, biomass, and richness of ground-dwelling invertebrates also are depressed. Since the shrub negatively affects invertebrates, vertebrates that feed extensively on insects, such as many songbirds, may also be negatively impacted.

At the study site, Morrow's honeysuckle has a density of nearly 68,000 shrubs/ha. In the understory, exotic cool season grasses and goldenrod dominate. Overall we identified 102 species of plants. The results of the study reveal that a foliar application of glyphosate is the cheapest and most effective method to control the shrub. Mechanically pulling up the shrub also is effective, but is labor intensive.

After removing the honeysuckle, new species of exotic plants invaded the areas. After removing the honeysuckle, native woody species actually decreased in abundance, in part due to browsing by overabundant deer. For restoration to be successful following honeysuckle removal, managers should: 1) follow-up treatments with another round of herbicide spraying to kill emerging exotics, 2) plant native herbs and seeds to help prevent the establishment of exotic plants, 3) plant native shrubs and trees, 4) control the deer herd from browsing the newly planted herbs and shrubs, and 5) maintain the area by periodic removal of exotics, mowing and/or prescribed fire. Following these recommendations should help restore both the historical and ecological landscape at Fort Necessity National Battlefield.

Executive Summary

Morrow's honeysuckle (*Lonicera morrowii* Gray) is one of a suite of exotic bush honeysuckle species that have become some of the most pervasive woody invaders in eastern North America. The shrub dominates a degraded meadow overlooking the replica of Fort Necessity. Not only does the shrub negatively impact native flora and fauna, but it also diminishes the historical landscape at Fort Necessity National Battlefield (FONE). This study seeks to examine which vertebrate, plant, and worm species are found in this novel community type, discover the most efficient method to eradicate the shrub, determine the impacts removal methods may have on native species, and assess the pros and cons of several management options for the meadow based on field data collected during 2004 – 2005.

Our study site (14.6 ha) was formerly an oak-hardwood forest, but was cleared for livestock grazing prior to establishment of the park in 1933. The pasture was maintained by mowing until the mid-1980s; it was thought that through passive management, native trees would become established, eventually approximating conditions that existed in the summer of 1754 when French and Indians hid amongst the trees, firing volleys at George Washington and his British troops within the hastily-built Fort Necessity. However, Morrow's honeysuckle invaded the meadow after mowing ceased, stifling recruitment and growth of native tree species.

To determine the best time to apply herbicides or mechanically remove the plant, we tracked total nonstructural carbohydrate (TNC) levels in the roots of Morrow's honeysuckle from March 2004 – February 2005. Large roots from five shrubs each month were collected, processed, and analyzed for TNC. Total nonstructural carbohydrates were lowest in May, immediately after leaf and flower formation; TNC levels were highest in October, as the leaves were beginning to senesce.

We tested 4 different treatment methods for removing Morrow's honeysuckle: 1) mechanical removal, 2) cutting the shrubs flush to the ground, 3) cutting the shrubs and applying a 20% solution of glyphosate (Roundup Pro), and 4) applying a foliar application of a solution of 2% glyphosate. We established 10 5×5 m plots of each treatment type, including 5 control plots, for a total of 45 plots. We compared treatments between two months, May and September, with 5 plots of each treatment type occurring in each of the two months. Prior to removal, we estimated mean ($\pm$ SE) density of Morrow's honeysuckle live stems at $176,000 \pm 9,960$ stems/ha and mean number of shrubs at $67,920 \pm 4,480$ shrubs/ha. Morrow's honeysuckle accounted for 93.6% of all live stems. The most abundant native woody shrubs include red maple (*Acer rubrum*) ($3,400 \pm 1960$ stems/ha), southern arrowwood (*Viburnum dentatum* var. *lucidum*) ($3,197 \pm 587$ stems/ha), waxyfruit hawthorne (*Crataegus pruinosa*) ($1,536 \pm 199$ stems/ha), black cherry (*Prunus serotina*) ($1,456 \pm 208$ stems/ha), and sweet crabapple (*Malus coronaria*) (729 ± 160 stems/ha). Mechanical removal in May was most effective at decreasing the number of shrubs (>91%) but was also the most labor intensive (933 hrs/ha). Cutting in September (13.8% reduction) and stump application of herbicide in September (29.1% reduction) were the least effective treatment methods. Foliar application had the least labor (56 hrs/ha) and cost ($\$770 \pm \$60$), but was only marginally successful in eradicating Morrow's honeysuckle shrubs (May: 66.4% reduction; September: 68.8% reduction). All treatment method-months decreased the number of native woody species, except for cut-May (+ 46.1%) and mechanical-September (+ 19.1%). We attribute the reduction of native woody species after treatments to 1) herbicide affecting non-target species, and 2) deer herbivory. Control plots had increased number of native shrubs; though the shrubs are thought to negatively affect recruitment, they also form barriers to

deer herbivory. Two new woody exotic species, autumn olive (*Eleagnus umbellata*) and tree of heaven (*Ailanthus altissima*) colonized the plots after shrub removal.

Within each of the 45 5×5 -m plots, we established 5 1×1 -m nested subplots to identify and record percent cover of herbaceous species. We calculated a number of different metrics to quantify the quality of the herbaceous community, including richness (S), Shannon-Weiner Index of diversity (H'), evenness (J'), as well as Floristic Quality Assessment (including mean coefficient of conservatism (mean C) and Floristic Quality Index (FQI)). Prior to removing Morrow's honeysuckle, we identified 93 herbaceous species; 68 species were native, while 25 species were exotic. The five species having the greatest pre-treatment percent cover were sweet vernal grass (*Anthoxanthum odoratum*) ($\bar{X} = 8.46\%$), wrinkleleaf goldenrod (*Solidago rugosa*) ($\bar{X} = 3.51\%$), early goldenrod (*S. juncea*) ($\bar{X} = 2.64\%$), northern dewberry (*Rubus flagellaris*) ($\bar{X} = 1.96\%$), and orchard grass (*Dactylis glomerata*) ($\bar{X} = 1.88\%$). Both sweet vernal grass and orchard grass are exotic cool season grasses. One species, slender wheatgrass (*Elymus trachycaulus*) ($n = 1$ subplot), is a state-listed species, having a state rank of S3. After removal, all metrics measuring herbaceous community quality were significantly different ($p < 0.05$), with the exception of total evenness and mean C. Mechanical removal in May and cut in September had the overall highest values for herbaceous quality, while foliar and stump application of herbicide had the lowest values. Overall, exotic species richness increased 28% ($n = 7$ new species) while native species richness increased 2.9% ($n = 2$ new species), revealing that exotic species quickly colonized areas devoid of honeysuckle.

American woodcock (*Scolopax minor*) are popular game birds, but their populations have declined over the past several decades due to afforestation and wetland degradation. To determine relative woodcock habitat quality at our study site, we 1) located and mapped the

singing grounds of the male birds from late winter – spring, 2) performed flush counts in the honeysuckle (~ 2 km of transects) to determine the relative abundance of woodcock in the study area, and 3) determined the location of earthworms, the bird's major prey, within the study area. In 2004 we performed singing ground surveys on 11 different occasions and mapped the location of 23 singing grounds. The mean number of birds heard calling each evening was 4. In 2005 we performed singing ground surveys on 8 different occasions and mapped 31 singing grounds; mean number of birds heard calling each evening was 5. The maximum birds seen or heard calling over both years was 11. Woodcock sang in open areas next to cover, including areas along the upper hiking trail that bisects the study area. To ensure the continued use of the study area by singing male woodcock, managers should leave open areas with native shrub/scrub cover. We performed flush counts on 12 occasions from March – November 2004. We flushed 5 woodcock. Most birds were flushed directly on the flush transect, possibly indicating that the actual thickets of shrubs are too dense for woodcock use. We found no sign of woodcock feeding (i.e., probe holes) in the study area. Overall flush counts were not an effective method to survey American woodcock at our study site.

Earthworms were sampled by digging a 30.5 cm circular hole and sorting the worms from the dirt. Deep-dwelling species were sample by pouring an organic mustard solution into the hole; the mustard solution irritates the skin of the worms so that they emerge from their burrows. Plots were established under 5 different shrub/tree species to assess which species worms prefer: black locust (*Robinia pseudoacacia*), tulip poplar (*Liriodendron tulipifera*), southern arrowwood, Morrow's honeysuckle, and open areas with no shrub cover. Soil moisture, soil chemistry, and soil temperature also was recorded from each plot. We collected 2,214 individuals of 4 species of earthworms, all of which are exotic: *Octolasion tyrtaeum* (44%

of total), *Eisenia rosea* (41%), *Lumbricus rubellus* (9%), and *L. terrestris* (6%). The earthworm species that occur at shallow enough depths for the 59 – 77 mm American woodcock beak include *L. rubellus*, *L. terrestris*, and *E. rosea*. These earthworm species were found in far greater abundances under tulip poplar than any other shrub. Morrow's honeysuckle and black locust also had high numbers of these earthworm species.

Overall, the study area serves as an important singing area for American woodcock and provides shelter for woodcock. To maximize American woodcock populations at FONE, it is necessary to maintain the important singing ground sites while at the same time maintaining early successional cover. A portion of the study area (the control area) should be maintained as quality early successional habitat. Morrow's honeysuckle should be removed from this area, but care should be taken to ensure that native shrubs and trees remain. Infrequent mowing (every 2-3 years) or prescribed fire should be used to maintain the early successional habitat at FONE.

We established 6 fixed radius (50 m) point counts to survey songbirds within the study area. Surveys took place once a month for an entire year (March 2004 – February 2005). We identified 33 bird species of 398 individual birds. Cedar waxwings (*Bombycilla cedrorum*) were the most numerous birds encountered ($n = 132$). Two bird species, the prairie warbler (*Dendroica discolor*) and golden-winged warbler (*Vermivora chrysoptera*) are birds of special concern.

We used Sherman live traps to sample small mammals at FONE. We established 8 80 × 120 m grids at FONE, 4 grids were located within the study area, while the other 4 were located outside the study area. Each grid consisted of 150 traps. We captured 11 species of small mammals at FONE ($n = 1,148$ individuals) in 24,009 trap nights. Common species included white-footed mouse (*Peromyscus maniculatus*) ($n = 596$), meadow jumping mouse (*Zapus*

hudsonius) ($n = 232$), meadow vole (*Microtus pennsylvanicus*) ($n = 124$), masked shrew (*Sorex cinereus*), and shorttail shrew (*Blarina brevicauda*) ($n = 83$). Removing the honeysuckle and maintaining quality early successional habitat would benefit some small mammals, such as meadow jumping mice; reforestation would benefit woodland jumping mice (*Napaeozapus insignis*). Other species would probably not be greatly affected by changes in habitat, because most are generalist species.

We used pitfall trap arrays and cover boards to sample herpetofauna within our study site. Six pitfall trap arrays (a triad design), each consisting of three 3 m lengths of drift fence and four 20 liter buckets, were randomly placed within the study area. Six cover board “cookies” – 5 cm thick slices of wood cut from an elm (*Ulmus* spp.) snag – were placed near the pitfall array to sample for terrestrial salamanders. We captured 6 species of amphibians, 2 species of reptiles, and 6 species of small mammals in 576 pitfall trap nights. We captured 1 species of amphibian (redback salamander (*Plethodon cinereus*; $n = 28$) and 1 reptile (eastern garter snake (*Thamnopsis sirtalis*; $n = 1$) from 432 flip-checks of the cover boards. From all our vertebrate surveys, we recorded 8 new species from the park, including 6 mammals, 1 reptile, and 1 amphibian. Removing the honeysuckle and maintaining quality early successional habitat will benefit most of the snake species, while reforestation will eventually become more conducive for terrestrial salamanders.

We devised four management options for the degraded meadow at FONE. The first option was “No action.” This option would be the least costly in the short run, but would fail to meet the park’s objective of “reestablishing the vegetative conditions that existed during the historical period.” If this option was chosen, the field will continue to be dominated by Morrow’s honeysuckle and other exotic plant species.

The second management option was “Remove Morrow’s honeysuckle and maintain entire study area as early successional habitat.” This option would create conditions similar to what existed prior to the mid-1980s when mowing ceased, though it would not approximate conditions that existed during the battle at Fort Necessity. This option would most benefit American woodcock, as well as grassland birds. Once the honeysuckle was removed, the area would have to be maintained by either periodic mowing or prescribed fire.

The third option was “Remove Morrow’s honeysuckle and restore the entire site to a deciduous forest.” This option would create conditions most similar to what existed during the mid-1750s. While American woodcock and early successional songbird species would use the habitat the first few years, as the forest matured, these species would slowly decrease and eventually disappear from the study area. This option would be the most expensive, because after honeysuckle eradication, the entire area would have to be reforested by planting native tree saplings.

The fourth, or preferred option, was “Remove Morrow’s honeysuckle and restore part of the study area to a deciduous hardwood forest, while maintaining the remaining area as quality early successional habitat.” This option would meet the park’s goal of both restoring the historical vegetative landscape around the fort while creating suitable habitat for American woodcock and other early successional plant and animal species. For control efforts, we suggest a late season (October) foliar application of glyphosate, followed by bush-hogging in May after remaining Morrow’s honeysuckle shrubs have leafed and flowered. A smaller area of the study site with thinly scattered Morrow’s honeysuckle (2.75 ha) should be controlled by mechanical removal. These two methods should eliminate most of the honeysuckle, but spot treatments would still have to be applied during the summer months. In the fall of the same year, the area

would need to be prepared for planting. If conditions are favorable, a prescribed fire should be used to burn the honeysuckle slash and prepare the seed bed. If burning is not an option, the area should be disked and/or chipped. Later in the fall, the area should be planted with seeds of native herbs and grasses throughout the study site to keep aggressive invasive species from colonizing and to create favorable early successional habitat for wildlife. After seedbed preparation in the fall, native saplings should be planted; approximately 6.04 ha of the study site closest to the fort would need to be planted with ~ 10,000 native tree saplings. Approximately 1,680 m of deer fencing would need to be erected around the reforest area. Both the early successional habitat and reforest area would need to be regularly maintained by annual spot treatment of herbicide and periodic fire and/or annual mowing.

Introduction

As human population and commerce continue to grow and expand, exotic plants continue to invade and spread, depressing native diversity and altering ecological functions. Morrow's honeysuckle (*Lonicera morrowii*), a shrub native to Japan, was introduced to the United States as an ornamental circa 1875 (Rehder 1940). The shrubs have been planted as shelterbelts in the midwest (Herman & Davidson 1997), used in mine reclamation (Wade 1985), and planted for wildlife use (Martin et al. 1951, Ripley et al. 1957, VanDruff et al. 1996). The shrubs' seeds are carried by birds and other wildlife (Ingold & Craycraft 1983, Vellend 2002). Today, Morrow's honeysuckle is naturalized in most northeastern and mid-Atlantic states, as well as southeastern and south-central Canada. Recent studies reveal that the shrubs decrease species richness and inhibit forest regeneration (Woods 1993, Collier et al. 2002, Gorchov & Trisel 2003, Hartman & McCarthy 2004). Honeysuckle shrubs also may increase the incidence of nest predation for some species of songbirds; branch architecture, the lack of thorns, and the low height of the shrubs may facilitate predation by raccoons (*Procyon lotor*), snakes, and other predators (Schmidt & Whelan 1999, Borgmann & Rodewald 2004). Moreover, dense thickets of the shrubs have been shown to decrease spider richness by reducing the structural complexity of the understory (Buddle et al. 2004).

The General Management Plan for Fort Necessity National Battlefield (FONE) states that "the forest will be managed to prevent damage by exotic species" and "the park will manage species to help maintain health and diversity within the ecosystem, to ensure the continuation of rare, threatened, or endangered species, and to work toward reestablishing the vegetative conditions that existed during the historical period whenever possible" (Fort Necessity National Battlefield 1991). At Fort Necessity National Battlefield, Morrow's honeysuckle has invaded a

degraded meadow on a hillside adjacent to the Great Meadows and the replica of Fort Necessity, altering the cultural landscape and impeding efforts to restore the site to its former historical and ecological condition (Fort Necessity National Battlefield 1991, C. Ranson, Fort Necessity National Battlefield, personal communication). Moreover, Morrow's honeysuckle may be the cause of recent declines in two native plant species of special concern at FONE, purple bluet (*Houstonia purpurea* var. *purpurea*) and bushy St. Johnswort (*Hypericum densiflorum*) (Western Pennsylvania Conservancy 2003).

Areas dominated by exotic plants have altered vegetative structure and resource availability. Resulting changes have the potential to decrease the carrying capacity of native flora and fauna (Scheiman et al. 2003). Dense thickets of exotic bush honeysuckles have created novel communities of flora and fauna that have yet to be thoroughly inventoried. While some species of flora and fauna are undoubtedly negatively affected by the presence of the exotic shrubs, other species may flourish under these new conditions. For this reason, it is important that a comprehensive inventory of flora and fauna is developed prior to attempts at restoration. Once a baseline of species inhabiting the honeysuckle community is established, more effective management decisions can then be developed based on the presence and relative abundance of species of conservation concern or management interest. A comprehensive ecological survey may also reveal species or conditions that may impede successful restoration, such as other exotic invasive species, soil nutrient deficiencies, and overabundant herbivores.

The park has two ultimate management goals for the study area. The first goal is to restore the site back to a native deciduous forest. The second goal is to maintain or improve American woodcock (*Scolopax minor*) habitat in the study area. American woodcock use early successional habitat and they are rarely found in mature forests, except along riparian areas. For

this reason, the goals of restoring the site to a native deciduous forest *and* improving woodcock habitat are conflicting management goals. However, we believe that the study area is large enough to accommodate both management goals – to both reforest the historical landscape adjacent to the replica of Fort Necessity *and* improve American woodcock habitat.

Objectives

The objectives of this study were to:

- 1) assess the best time (according to shrub's phenological stage) to apply herbicide or mechanically remove Morrow's honeysuckle;
- 2) determine the most effective and cost-efficient method to eradicate Morrow's honeysuckle and the effect these techniques may have on the herbaceous understory;
- 3) determine the relative abundance and location of American woodcock (*Scolopax minor*) within the study area as well as its major prey, earthworms;
- 4) determine the relative abundance and richness of bird species within the study area;
- 5) determine the relative abundance and richness of small mammals within the study area;
- 6) assess the relative abundance and richness of amphibians and reptiles within the study area;
- and
- 7) develop a set of management options for the removal of Morrow's honeysuckle and the consequences each of these options may have on flora and fauna within the study area.

Site Description

Fort Necessity National Battlefield is a 350.5 ha historical park located in Fayette County in southwestern Pennsylvania (39°48'43" N, 84° 41'50" W) (Figure 1). The park lies in the Allegheny Mountains of the Appalachian Plateau, an area also known as the southern Laurel Highlands. The battlefield straddles an upland valley between Chestnut Ridge and Laurel Hill. Land within the park is rolling and well-drained, with the exception of the Great Meadows, a wet meadow complex in the northern corner of the park. Elevations within the park range from 535 – 710 m (Fort Necessity National Battlefield 1991).

Low lying areas are characterized by Philo silt loams. These soils are deep, poor to moderately drained, medium textured, and were formed from acidic sediments derived from sandstone and shale. Upland sites within the meadow consist of Brinkerton and Armagh silt loams, Cavode silt loams, and Gilpin channery silt loams. These soils are moderately deep, moderate to well drained, medium-textured, and underlain by acidic shale and sandstone bedrock (Kopas 1973).

The climate is moderate continental. The average annual temperature is 9° C. Mean winter temperature is -3° C and mean summer temperature is 22° C. Average annual precipitation is 119 cm (Fort Necessity National Battlefield 1991).

The study site is located on a hillside west of the replication of Fort Necessity (Figure 2), a hastily-built fort constructed by George Washington and his troops in 1754 at the onset of the French-Indian War. The hillside was formerly an oak-hardwood forest, but was cleared for pasture prior to the establishment of the park in 1933 (Fort Necessity National Battlefield 1991). Pollen samples taken from cores near the fort reveal that oaks (*Quercus* spp.), hickories (*Carya* spp.), birch (*Betula* spp.), American beech (*Fagus grandifolia* Ehrh.), and red maple (*Acer*

rubrum L.) were the major components of the forest prior to clearing (Kelso 1994). The pasture was maintained by mowing until the mid-1980s, at which time mowing ceased. It was thought that passive management would allow natural succession to occur, permitting the meadow to be eventually reforested by native hardwoods (C. Ranson, Fort Necessity National Battlefield, personal communication). However, reforestation never occurred and today the pasture is characterized by a dense cover of Morrow's honeysuckle and other exotic species (Fort Necessity National Battlefield 1991) (Figure 3).

Because one of the goals of the original study was to compare site characteristics, including flora and fauna abundance and diversity, between conditions prior to the honeysuckle removal to conditions after the honeysuckle removal, we divided the study area into two main areas: a control and a treatment. The control area (7.64 ha) lies approximately 500 m to the west of the replica of Fort Necessity, while the treatment area (6.04 ha) lies 50 m to the west of Fort Necessity, on the adjacent hillside (Figure 2). The study design, including the woodcock transects, bird counts, pitfall trapping, and small mammal live trapping, was set-up with this overall goal in mind, so that equal surveys/trap locations were established in both the control and treatment areas (e.g., 3 bird counts in the control and 3 in the treatment, 2 small mammal grids in the control and 2 in the treatment, etc.). In addition, we included a low-lying area between the treatment and control area in the study area, though we separated it from the treatment and control because of its sparse cover of Morrow's honeysuckle and higher moisture gradient. Subsequently, we named this area "wetland" (0.96 ha) (Figure 2).

Methods

Total nonstructural carbohydrates

Relating total nonstructural carbohydrate (TNC) levels to plant phenological stages allows resource managers to know when the best time is to mechanically remove or apply herbicide to undesirable plant species (Sosebee 1983). We randomly chose 5 Morrow's honeysuckle shrubs per month (March 2004 – Feb. 2005) and collected root samples. We used a pulaski to pry the plant from the ground and used pruning shears to collect the roots. From each shrub we selected the largest possible root that could be cut with the pruning shears. Prior to collection, the phenological stage (dormant, bud break, leaf development, seed formation, seed maturation, or leaf fall) of the plant was noted (Sosebee 1973, Conway et al. 1999). The roots were placed on dry ice to prevent enzymatic degradation of TNC (Bóo & Pettit 1975, Wilson et al. 1975). The roots were dried in a drying oven at 100° C for 1-2 hours. Afterwards, the roots were dried at 60-65° C for one week to remove moisture (Bóo & Pettit 1975). After drying, the bark was carefully removed, as well as any heartwood or decayed areas in the wood, so that only sapwood remained. The sapwood was then ground in a Wiley mill fitted with a 1 mm screen. Ground Morrow's honeysuckle roots were analyzed using the anthrone reagent procedure (Yemm & Willis 1954, Conway et al. 1999). For interpretation, we charted the TNC levels throughout the year and related the measurements to the shrubs' phenological stage. We then used the resulting graph to denote the most effective time to apply herbicide or mechanically remove the shrub.

Assessing Morrow's honeysuckle removal methods

We tested 4 different treatments in removing Morrow's honeysuckle: 1) mechanical removal, 2) foliar application of glyphosate herbicide (Roundup Pro™), 3) stump application of glyphosate herbicide (Roundup Pro™), and 4) cutting the shrub flush to the ground. We established 10 5 × 5 m plots of each treatment type, including 5 control plots, for a total of 45 plots. We compared treatments between 2 seasons (late spring vs. late summer), with 5 plots of each treatment type occurring in the spring and the remaining 5 plots of each treatment type occurring in the fall. Plots were systematically randomly placed along transects. There was a buffer of 5 m between plots to ensure that the treatments did not interfere with one another. All plots were located > 10 m from the edge of the forest. The plots were established in the treatment area of the study site and were set apart from other studies (e.g., small mammal grids) to reduce interference and/or impact (Figure 4).

Mechanical removal was accomplished by pulling up the plants by hand and by the use of a pulaski. Care was taken to remove all large roots to lessen the likelihood of resprouting (Nyboer 1992). Native shrubs were left in place.

Foliar application of glyphosate occurred on relatively calm days when there was little chance of rain. A standard backpack sprayer was used to apply a 2% glyphosate solution to the foliage of the shrubs. The backpack sprayer was set at high pressure to ensure complete coverage of the shrubs. Care was taken to ensure that no native shrubs were sprayed. All herbicide treatments occurred on the same day.

A chainsaw was used to cut Morrow's honeysuckle in the stump herbicide plots. All stumps were cut approximately 5 cm above the ground. Cut shrubs were removed from the plot.

Native shrubs were left standing. A backpack sprayer containing a 20% glyphosate solution and set at low pressure was used to treat the cut stumps.

We also used a chainsaw to cut the shrubs in the cut-shrub plots. The shrubs were cut approximately 5 cm above the ground. Cut bushes were removed from the plot. Native shrubs were left standing.

We evaluated the cost and time (person-hrs.) of each method. These figures were calculated on a per-hectare basis.

Within each 5×5 m plot, Morrow's honeysuckle and other woody vegetation was identified to species, counted (stem count), basal stem diameter measured, and percent cover estimated. We established five 1×1 m subplots within the 5×5 m plot; 4 of the subplots were located in the corners of the plot and one subplot was located in the middle of the plot. Herbaceous vegetation was identified to species and assigned a cover class within these nested subplots. Treatments took place once in late May and once in mid-September to test for differences of treatments between seasons when total nonstructural carbohydrate levels were assumed to be near their lowest and highest, respectively. Vegetation measurements took place a few days prior to treatments. Vegetation for all treatments was re-measured in May and again in August (2005) when goldenrod (*Solidago* spp.) and asters (*Symphyotrichum* spp.) are easier to identify. Nomenclature follows Kartesz (1999).

We used analysis of covariance (ANCOVA) (PROC GLM, SAS version 9.1; SAS Institute, Inc., Cary, NC, U.S.A.) to compare Morrow's honeysuckle shrub cover, stem density, shrub density, and native shrub density. Duncan's multiple range tests were used for post hoc pairwise comparisons. Pre-treatment cover, stem density, and shrub density was used as the covariate. The dependent variable was shrub cover, stem density, and shrub density; the

independent variables were the methods of treatment and the season the treatments were applied. We assumed that change in stem density and percent cover was the result of the different treatments and the timing (season) of the treatments. We also assumed that differences in environmental conditions (e.g., soil nutrient content, moisture level, etc.) among plots were not significantly different.

We used several indices, including species richness (S), Shannon-Weiner index of diversity (H'), and Pielou (1966) evenness index (J') to evaluate differences in the herbaceous layer between pre-treatment and post-treatment, between the two seasons of treatments, and among the different treatment types. The Shannon-Weiner Index (H') takes into account both the number of species, as well as their equitability. This index assumes all species are represented in a sample and that the sample was obtained randomly: $H' = - \sum p_i (\ln p_i)$ where p_i is the proportion of individuals found in the i th species. Values for the Shannon-Weiner Index for real communities typically fall between 1.5 and 3.5 (Magurran 1988). Since the calculated value of H' fails to show the degree that each factor (species richness and evenness) contributes to diversity, we also calculated species evenness (J'). Species evenness was calculated as $J' = H'/H'_{\max}$, where $H'_{\max} = \ln(S)$ (Pielou 1966). We used coefficient of conservatism (C) values developed for plants in West Virginia (J. Rentch 2005, West Virginia University, Morgantown, unpublished data) to determine mean C and Floristic Quality Index (FQI) scores for pretreatment herb subplots, as well as post-treatment herb subplots. The Floristic Quality Index is a somewhat subjective, but still quantitative, measurement of an herbaceous community's quality (Swink & Wilhelm 1994). A species coefficient of conservatism value (from 0-10) reflects the ecological specializations that a plant displays to a specific habitat or set of environmental conditions; the herbaceous

quality of an area is a function of the richness of conservative plant species. A floristic quality assessment has 2 separate measures: 1) the average coefficient of conservatism, or mean C, which is calculated by taking the sum of the coefficient of conservatism values and dividing them by the number of native species, and 2) the Floristic Quality Index, which is calculated by multiplying the mean C by the square-root of the total number of native species. We followed the recommendations of Bernthal (2003) and reported both mean C and FQI scores. We used analysis of variance (ANOVA) (PROC GLM, SAS version 9.1) to compare pre-treatment and post-treatment means between months, among treatment methods, among treatment method $\times$ month, and among treatment method-month; we used Duncan's multiple range tests to compare differences between pairs. Independent variables were months treatments were applied and treatment methods. We assume that differences observed among plots were the result of the type and timing of treatments. All shrub and herb variables were tested for normality; if assumptions for normality were not met, the variables were appropriately transformed prior to statistical analysis. Level of significance for all tests was $\alpha = 0.05$.

American woodcock

Introduction

American woodcock are popular game birds in the eastern and midwestern portion of the United States. However, the number of American woodcock has been declining at approximately 2.5% per year since 1968 (Kelley 2001). Because of its decline, the bird is now listed on the Audubon Watchlist (<http://www.audubon.org/bird/watch>). Woodcock prefer wetlands and early successional habitat to forage for earthworms and nest; unfortunately, both of these habitats have been declining due to wetland destruction and afforestation (Dwyer et al.

1983, Sauer & Bortner 1991). Informal surveys at FONE revealed a relatively large number of American woodcock located in the study area and adjacent Great Meadow (C. Ranson, Fort Necessity National Battlefield, personal communication).

Our specific objectives for this portion of the study were to 1) locate and map the singing grounds of the male birds; 2) perform flush counts in the honeysuckle to assess the relative abundance of the woodcock within the study area; and 3) determine the spatial location and identify the habitat where earthworms, the woodcock's major prey, are located within the study area.

Singing ground surveys

A common method to detect the presence and relative abundance of American woodcock is to listen to the song and observe the courtship display of the male bird in late winter through spring (Mendall & Aldous 1943, Dwyer et al. 1983). In 2004 and 2005, we began our singing ground surveys at the end of February when the males begin their courtship song and display. The males give a distinctive "Peent, peent, peent" call before rising into the air nearly 90 m; their singing then turns into a bubbling warble as they sail back down to their singing ground. Our singing survey ended in mid-May when the male woodcock ceased singing and displaying. We performed the surveys once a week, mapping the location of the singing grounds using a GPS unit. These points were then downloaded into GIS software (ArcGIS 9.0) so that the singing grounds could be displayed as a layer on a recent aerial photo of the park. We then examined the map to determine areas where singing grounds were most abundant in order to help guide restoration efforts within the study area. Because some nights it was not possible to locate and map every singing ground location, we simply estimated the total number of woodcock calling.

Flush counts

Flush counts are commonly used to estimate the number of woodcock in a given area (Wishart & Bider 1976). We established several flush transects in the thickets of Morrow's honeysuckle. Transects were chosen in a systematic non-random fashion, with the initial transect located a random distance (between 0 and 50 m) from the edge of the plot (Burnham et al. 1980). Subsequent transects were located 50 m from this initial transect. All transects ran parallel to one another. Because of the dense vegetation, narrow paths were cleared through the thick growth of honeysuckle using Swede axes. In the control area we established 1,050 m of transects, while in the treatment area we established 900 m of transects. One transect line of 100 m was established in the wetland area. Flush counts were performed approximately twice per month, using 2 observers, from March 2004 – November 2004.

In addition to mapping birds flushed from the woodcock transects, we also mapped the locations of birds randomly flushed while we were hiking or working in the study area. These locations were also GPS'ed and downloaded into ArcMAP (ArcGIS 9.0) so that the points could be displayed on a recent aerial photo of the park. When a woodcock was flushed, either along a transect or randomly, we thoroughly searched the area for signs of nesting or feeding (i.e., probe holes in the soil from the bird's long beak).

Earthworms

Fifty to 90% of the American woodcock diet consists of earthworms. For this reason it is important to understand the relative abundance of earthworms, as well as their spatial and temporal locations, to better manage for woodcock (Sepik et al. 1981). Managing earthworms in areas with exotic plant species is not well addressed - earthworms existing in the soil may prefer

to live underneath certain plants. Previously farmed land with moderately drained soil, like the study site at FONE, was found to have an extremely high biomass of earthworms (Owen & Galbraith 1989). Owen and Galbraith (1989) found American woodcock inhabiting sites with abundant earthworm communities; however, unlike Owen and Galbraith's (1989) study, the study site at Fort Necessity is dominated by Morrow's honeysuckle. Knowledge of earthworm abundance and species composition under Morrow's honeysuckle versus under other native shrubs and trees on the study area will help guide management decisions for American woodcock at FONE.

Earthworms were sampled in May, July, and August of 2004 and in May, June, and August of 2005. Approximately 50 circular pits with a diameter of 30.5 cm were dug during each sampling period (Heneghan 2004, DePaul University, Chicago, Illinois, personal communication), under 5 different types of shrub/tree cover: black locust (*Robinia pseudoacacia*), tulip poplar (*Liriodendron tulipifera*), southern arrowwood (*Viburnum dentatum* var. *lucidum*), Morrow's honeysuckle, and in open areas without shrub cover.

A circular, open-bottomed metal frame was driven into the ground to delineate the sample area (Kourtev et al. 1999). The frame was then pulled-up and the delineated plot was dug with a spade to a depth of 20 cm (Aplet 1990, James 1991). Soil was hand-sorted and worms separated by species. Worms were killed by immersion for a few seconds in nearly boiling water (Beyer & Cromartie 1987). The worms were then counted, blotted on paper towels to remove excess water, and immediately weighed to determine biomass (Aplet 1990). Digging and hand-sorting is a commonly used method of effectively collecting epigeic (litter-dwelling) and endogeic (soil-dwelling) earthworms (Saetre 1998, Spurgeon & Hopkin 1999, Kalisz & Powell 2000). To adequately sample anecic species (deep-burrowing), as well as epigeic and

endogeic species during unfavorable conditions, a method of extraction needed to be used (Spurgeon & Hopkin 1999). A mustard and water suspension was used to extract anecic species from their burrows (Gunn 1992). After removing the soil and earthworms, the extractant was applied to the dug pits (Lee 1985). Those earthworms extracted were placed in the ziplock bag for that specific location. Adult and juvenile worms were identified to species and biomass was recorded.

Prior to sampling for earthworms, soil samples from the “plug” of dirt were placed in a zip-lock bag, labeled with the location, air-dried, and taken to a nearby lab for analysis of soil chemistry (i.e., pH, available soil organic matter, nitrogen [N], phosphorus [P], potassium [K], calcium [Ca], sulfur [S], sodium [Na], boron [B], iron [Fe], manganese [Mn], copper [Cu], zinc [Zn], aluminum [Al], and magnesium [Mg]). In addition to soil chemistry, the following measurements were taken from each earthworm-sampling plot: identification and percent cover of herbaceous species, soil temperature, and % soil moisture. To obtain soil moisture, a 20 g subsample of soil was weighed in the lab, dried for 48 hrs. at 70° C, and weighed again.

Songbirds

Early successional habitat at FONE has been degraded because of the invasion of Morrow’s honeysuckle; the proliferation of honeysuckle is thought to be partly responsible for the decline of early successional/grassland birds in the park (Yahner et al. 2004). We used fixed radius point counts (50 m radius circular plots) to survey birds (Reynolds et al. 1980, Ralph et al. 1993, Ralph et al. 1995, Hamel et al. 1996). Point counts lasted for 5 min at each station. Longer point count duration has been shown to increase the standard error of counts (Smith et al. 1998). Because of the small size of the study sites, only 6 plots were able to be placed within the

study area (3 in control area, 3 in treatment area) (Figure 4). The protocol for bird counts recommends that bird count stations be separated by > 250 m (e.g., Hamel et al. 1996); we were unable to meet these recommendations because of the small size of the study area, so that the outer boundary of some of our stations were only separated by ~ 75 m. For this reason it is possible that some birds may have been counted twice. Surveys took place once a month for one entire year (March 2004 – February 2005) to sample both breeding and non-breeding birds. Sampling took place in the morning before 1000 hrs.

A simple list of birds encountered during point counts may not reveal to what degree the birds are using the Morrow's honeysuckle habitat, because many birds are encountered as flyovers or are found mainly on the edge of the study area, at the interface of the forest-shrub habitat. We refined the list by indicating which species were considered flyovers (not actively using the habitat), nesting (nesting within the study area), foraging (foraging within the study area, but not nesting), and edge (encountered at the forest-shrub interface, but not the interior portion of the study area). These criteria were developed both from point count observations and by casual observations made while performing other field studies with the study area.

Small mammals

Small mammals can be an integral part of an ecosystem in dispersing seeds, ingesting invertebrates, creating holes and underground tunnels, and as a source of food to vertebrate species at higher trophic levels (Mazzotti et al. 1981, Longland & Clements 1995, Pearson et al. 2001). Few studies on small mammals have been conducted in areas with a species of *Lonicera* on site (McCay & Storm 1997), and no studies have been conducted within a site dominated by Morrow's honeysuckle. Pearson et al. (2001) noted that studies are lacking that examine effects

of exotic plants on small mammal communities, yet current research suggests that exotic plant invasions, especially Morrow's honeysuckle, have a high potential to alter small mammal ecology. As Morrow's honeysuckle out-competes and replaces native vegetation, natural habitats may be altered for small mammals. For this reason, it is important that small mammal surveys be carried out to assess the relative abundance and species richness of small mammals in these novel plant communities. The results can then be used to help guide management decisions within the study area.

Trapping occurred on 8 locations (grids) throughout FONE in April, June, and August of 2004 and in May, June, and July of 2005. We used a grid pattern of 10 transects with 15 traps on each line spaced at 8 m intervals (80 x 120 m grids). Four grids were completely within the Morrow's honeysuckle (Figure 4). The four remaining grids were located outside the study area; two grids were located in fields while the other two were located in forested habitat (Appendix I). Traps were set and checked for 4 days. Traps were baited with peanut butter and rolled oats wrapped with wax paper (O'Dell, University of Arizona, Tucson, Arizona, pers. comm.). When a small mammal was captured in a collapsible Sherman live trap (Small Folding Galvanized (SFG), 5 x 6.4 x 16.5 cm), a plastic bag was used to hold the animal while recording the following data and measurements: date and time of processing, identification of specimen to species, size of specimen (total length, tail length, right ear length, right hindfoot length, and weight), age (adult or juvenile), sex, reproductive condition (female: null, lactating, or pregnant; male: abdominal or testes length), and trap location (McDiarmid & Wilson 1996). Any comments also were recorded if needed. Every mouse and vole received a #1005-1 monel ear tag (National Band and Tag Company, Newport, Kentucky 41072-0430) because all mice and

voles on the sites have ear pinnae large enough to support the tag. Shrews and moles were toe-clipped. Animals were released at the trap station where they were caught.

Amphibians and reptiles

Few studies exist that have attempted to document the richness and relative abundance of reptiles and amphibians found in areas dominated by shrub honeysuckles (McEvoy & Durtsche 2004). We used pitfall traps combined with coverboards to increase our chances of sampling a diverse array of reptiles and amphibians (Gibbons & Semlitsch 1981, Monti et al. 2000).

Population sizes, seasonality, migration patterns, diversity, and distribution can be determined. By sufficiently sampling the study sites, a valuable data set will be available for habitat management at Fort Necessity National Battlefield.

Six pitfall drift-fence arrays were installed randomly throughout FONE. Each array consisted of three, 3 m long, 50 cm high (10 cm below the ground) silt-fence arms arranged in a triad design as proven effective by Gibbons & Semlitsch (1981) (Appendix II). A 5 gallon (20 liter) plastic bucket was installed at the end of each silt-fence arm and in the center of each array. Four buckets per array amounted to 24 buckets throughout the site. A wet sponge was placed in the bottom of each bucket to prevent desiccation and heat stress of the specimens. Pitfall arrays were opened for 4 consecutive nights in May, June, and August 2004 and May, June, and July 2005. Pitfalls were checked twice daily to minimize the mortality to herpetofauna and small mammals. Small mammals were ear tagged or toe clipped, depending on the genus. Total body length and snout-vent length were recorded for salamanders and snakes.

A total of 36 cover board “cookies” were placed in the study area in February 2004. The cover objects were 5 cm thick “cookies” cut from an American elm (*Ulmus americana*) snag. The “cookies” were approximately 30.5 cm in diameter, a size recommended by the Patuxent

Wildlife Research Center's Terrestrial Salamander Monitoring Program: Recommended Protocol for Running Cover Object Arrays (<http://www.im.nbs.gov/sally/sally4.thml>). Previous pilot studies using sawed "cookies" from the boles of trees as cover objects showed a relatively high incidence of use by terrestrial salamanders (J. Love, personal observation). Six cover board "cookies" were placed near each pitfall trap array; three were placed 10 m north of the center bucket of the pitfall array and 3 were placed 10 m south of the center bucket. The cover board "cookies" were separated by 8 m to eliminate bias based on recapture distances for several species of salamanders (Mathis et al. 1995). The boards were checked twice (at the beginning and end of each pitfall trapping period) during each of the six pitfall drift-fence trapping regimes conducted in 2004 and 2005.

Results

Total nonstructural carbohydrates

Total nonstructural carbohydrate levels were lowest in May immediately after leaf formation; TNC levels were highest in October as the leaves were beginning to turn yellow (Figure 5).

Assessing Morrow's honeysuckle removal methods

Prior to removal, the mean percent cover ($\pm$ SE) of Morrow's honeysuckle was $82 \pm 2\%$. Mean ($\pm$ SE) live Morrow's honeysuckle pre-treatment stem density was 441.5 ± 24.9 stems/plot ($176,000 \pm 9,960$ stems/ha); mean density of dead Morrow's honeysuckle stems was 188.1 ± 11.9 stems/plot ($75,240 \pm 4,760$ stems/ha). Mean density ($\pm$ SE) of Morrow's honeysuckle shrubs was 169.8 ± 11.2 shrubs/plot ($67,920 \pm 4,480$ shrubs/ha). Mean diameter ($\pm$ SE) of live Morrow's honeysuckle stems was 7.49 ± 0.15 mm, while dead stems averaged 6.26 ± 0.12 mm. The mean number of stems per plant was 3.85 ± 0.06 .

Besides Morrow's honeysuckle ($n = 28,330$ stems), we identified 20 additional seedlings, shrubs, and woody species within the 45 plots: southern arrowwood (*Viburnum dentatum* var. *lucidum*; $n = 416$ stems); red maple (*Acer rubrum*, $n = 384$ stems); waxyfruit hawthorne (*Crataegus pruinosa*, $n = 182$ stems); black cherry (*Prunus serotina*, $n = 164$ stems); multiflora rose (*Rosa multiflora*, $n = 116$ stems); sweet crabapple (*Malus coronaria*, $n = 86$ stems); gray dogwood (*Cornus racemosa*, $n = 35$ stems); common serviceberry (*Amelanchier arborea*, $n = 32$ stems); white oak (*Quercus alba*, $n = 14$ stems); black locust (*Robinia pseudoacacia*, $n = 10$ stems); tulip poplar (*Liriodendron tulipifera*, $n = 7$ stems); nannyberry (*Viburnum lentago*, $n = 7$ stems); Japanese barberry (*Berberis thunbergii*, $n = 6$ stems); summer grape (*Vitis aestivalis*, $n =$

5 stems); black gum (*Nyssa sylvatica*, n = 4 stems); sugar maple (*Acer saccharum*, n = 2 stems); flameleaf sumac (*Rhus copallinum*, n = 2 stems); white ash (*Fraxinus americana*, n = 1 stem); northern red oak (*Quercus rubra*, n = 1 stem); and sassafras (*Sassafras albidum*, n = 1 stem).

Two woody plant species, multiflora rose and Japanese barberry, are exotic.

One year after treatments, we found no significant differences in Morrow's honeysuckle cover between post-treatment months ($F_{[1, 34]} = 12.05, p = 0.0014$), though there were significant differences among treatment methods ($F_{[4, 34]} = 27.65, p < 0.0001$) and treatment method $\times$ month ($F_{[4, 34]} = 4.21, p = 0.0071$). There were significant differences among post-treatment method-month ($F_{[9, 34]} = 15.52, p < 0.0001$) (Table 1). Mechanical removal in May was the most effective method for reducing cover of Morrow's honeysuckle, while cutting the shrubs in September was the least effective. After shrub removal, we found significant difference in the number of live Morrow's honeysuckle stems between months ($F_{[1, 34]} = 47.30, p < 0.0001$), among treatment methods ($F_{[4, 34]} = 23.69, p < 0.0001$), and among treatment method $\times$ month ($F_{[4, 34]} = 7.13, p = 0.0003$). We also found significant differences among treatment method-month ($F_{[9, 34]} = 21.57, p < 0.0001$) (Table 1). Mechanical removal in May was the most effective method for reducing the number of Morrow's honeysuckle stems, while stump application of glyphosate in September was the least effective at reducing the number of stems, followed by cutting the shrubs in September. We also found significant differences in post-treatment shrub density between months ($F_{[1, 34]} = 20.87, p < 0.0001$), among treatments ($F_{[4, 34]} = 19.68, p < 0.0001$), and among treatment $\times$ month ($F_{[4, 34]} = 5.21, p = 0.0022$). We found significant differences in post-treatment shrub density among treatment methods-months ($F_{[9, 34]} = 14.69, p < 0.0001$) (Table 1). Mechanical removal in May was the most effective method to reduce density of Morrow's honeysuckle shrubs; cutting shrubs in September was least effective. For all post-treatment

methods-months, sprouts made up >98% of all live Morrow's honeysuckle stems, except for foliar-May (73.6%) and foliar-September (86.6%).

Following shrub removal, the number and type of native woody species varied according to treatment method-month, though no novel native woody plants were recorded. However, two previously unrecorded exotic woody species, autumn olive (*Elaeagnus umbellata*) ($n = 2$ plots) and tree of heaven (*Ailanthus altissima*) ($n = 2$ plots) were recorded. Post-treatment native shrub density did not differ significantly between months ($F_{[1, 12]} = 1.19, p = 0.1177$), among treatment methods ($F_{[4, 12]} = 1.43, p = 0.2841$), and treatment method $\times$ month ($F_{[4, 12]} = 2.19, p = 0.1320$), or among treatment method-month ($F_{[9, 12]} = 2.19, p = 0.1031$) (Table 2). Exotic species (excluding Morrow's honeysuckle) accounted for <3.0% of all woody stems. Native woody stems accounted for <9.1% of all woody stems, with the exception of mechanical-May plots, where native woody stems accounted for 46.9% of all live stems. Morrow's honeysuckle accounted for >90% of all woody stems for all treatment methods-months except for mechanical-May plots, where Morrow's honeysuckle was reduced to 53.1% of all woody stems.

The time and cost of each of the four treatment methods varied (Table 3). Foliar application of herbicide was the least time-consuming treatment, as well as the least expensive. Mechanical removal was the most time-consuming and costly.

We identified 93 herbaceous species ($\bar{X} = 16.0, SE = 0.26$) during our pre-treatment survey (Appendix III). Mean ($\pm SE$) pre-treatment total cover was $36.5 \pm 1.3\%$. We recorded 68 native species ($\bar{X} = 8.6, SE = 0.2$) with a mean cover of $18.8 \pm 0.9\%$, while 25 exotic species ($\bar{X} = 7.4, SE = 0.2$) had a mean cover of $17.7 \pm 0.9\%$. Mean Shannon-Weiner index of diversity (H') for pre-treatment subplots was 2.15 ± 0.03 ; mean evenness (J') was 0.78 ± 0.01 . Mean coefficient of conservatism was 3.53 ± 0.03 , while the Floristic Quality Index of all pre-

treatment plots averaged 10.27 ± 0.12 . The 5 species having the greatest pre-treatment percent cover were sweet vernal grass (*Anthoxanthum odoratum*) ($\bar{X} = 8.46\%$), wrinkleleaf goldenrod (*Solidago rugosa*) ($\bar{X} = 3.51\%$), early goldenrod (*S. juncea*) ($\bar{X} = 2.64\%$), northern dewberry (*Rubus flagellaris*) ($\bar{X} = 1.96\%$), and orchard grass (*Dactylis glomerata*) ($\bar{X} = 1.88\%$). Both sweet vernal grass and orchard grass are exotic cool season grasses.

One plant, slender wheatgrass (*Elymus trachycaulus*), is a Pennsylvania state-listed plant, having a rank of G5S3. It was found in both pre- and post-treatment plots. A voucher specimen of a former state-listed species, adderstongue fern (*Ophioglossum vulgatum*), was sent to the Carnegie Museum of Natural History in Pittsburgh; the specimen represented the 46th known population in Pennsylvania. As of February 2006, adderstongue was de-listed from the state rare list because several more populations of the plant had been documented in Pennsylvania (B. Isaac 2006, Curator, Carnegie Museum of Natural History, Pittsburgh, PA). It was found in plot 20-1 in the honeysuckle removal plots, as well as in 3 other areas of the park; slender wheatgrass was found in plot 36-1 and 44-5. A voucher specimen of slender wheatgrass is included in a book of pressed and identified plants that will be presented to the park at the end of the project. We used a GPS unit to download the coordinates of the rare plants so that their locations could be displayed on a map (Appendix IV). In addition, we found several populations of another state-listed plant, purple bluets (*Houstonia purpurea* var. *purpurea*) within the study area. This plant has the northern portion of its range in Pennsylvania and has a rank of G5S1. We did not map the new locations of purple bluets because the plant was fairly common within the study area and has been found in abundance within other areas of the park (E. Zimmerman 2004, Natural Community Ecologist, Western Pennsylvania Conservancy, personal communication).

A list of state-listed rare plants and animals found at Fort Necessity National Battlefield can be found in Appendix IV.

After removal, all metrics measuring herbaceous community quality, with the exception of total evenness and mean coefficient of conservatism, were significantly different ($p < 0.05$) among treatment method-month (Table 4). Mechanical treatments in May and cut treatments in May had some of the highest values for herbaceous communities, while foliar application of herbicide in September had the lowest values. We recorded a total of 102 species in post-treatment herb plots; 70 species were native and 32 species were exotic. Notable new exotic species include spotted ladythumb (*Polygonum persicaria*) ($n = 2$ subplots) and smooth brome (*Bromus inermis*) ($n = 9$ subplots). Overall, post-treatment native species richness increased by 2.9%, while exotic species richness increased by 28.0%. The state-ranked species, slender wheatgrass ($n = 1$ subplot), was recorded in post-treatment surveys. A list of all pre- and post-treatment herbaceous and woody species, their exotic/native status, and their coefficient of conservatism values can be found in Appendix VI. A complete list of all flora recorded at FONE can be found in Appendix VII.

American woodcock

Singing ground survey

In 2004 we performed singing ground surveys on 11 different occasions and mapped 23 American woodcock singing grounds (Figure 6). We concentrated our efforts in the study area, though we also heard woodcock calling in the Great Meadows west of the fort. The mean number of birds heard calling each evening (excluding the 2 evenings where no woodcock were heard) was 4. The maximum number of male woodcock heard calling was 6.

In 2005 we performed singing ground surveys on 8 different occasions and mapped 31 American woodcock singing grounds (Figure 7). During this survey we also included the Great Meadow area west of the fort and north of the treatment area. The mean number of birds heard calling each evening was 5. The maximum number of birds heard or seen was 11.

Although no quantitative ecological measurements were taken to attempt to describe the singing grounds, we observed that the majority of singing grounds were in open areas adjacent to escape cover. The most frequently used singing grounds were located on the hiking trails within the study area (Figures 6 & 7).

Flush counts

We performed flush counts on 12 different occasions from March 2004 – November 2004 and flushed 5 American woodcock (Figure 6). Four of the 5 woodcock were flushed directly on the trail, while one was flushed 2 m from the trail. We did not find signs of woodcock feeding or nesting from these locations. Additionally, we encountered 8 white-tailed deer (*Odocoileus virginianus*), 3 field sparrow (*Spizella pusilla*) nests, and 1 eastern garter snake (*Thamnopsis s. sirtalis*).

In 2004 we randomly flushed American woodcock from 8 locations; no sign of feeding or nesting was found from these areas (Figure 6). In 2005 we randomly flushed 8 woodcock; all locations were either in the northern portion of the treatment area or near the nursery (Figure 7). We did not find any sign of feeding or nesting from these 5 locations.

Earthworms

We collected 4 species of earthworms, all of which are exotic, introduced earthworms in the Family Lumbricidae. This family is also known as the “peregrine” earthworms because of their ability to travel great distances. *Eisenia rosea*, also called the pink soil earthworm, is an

endogeic species (soil dweller) of two size morphs and may be found in a tightly coiled pink ball during aestivation in hot, dry summers (Gregory & Hebert 2002). *Lumbricus rubellus*, also known as the red marsh earthworm, is a medium sized epi-endogeic (litter dweller) species with dark red pigmentation that inhabits the upper organic layers of the soil. *Octolasion tyrtaeum*, also called the woodland white earthworm, is a medium-sized endogeic (soil dweller) species with very little pigmentation that typically inhabits soil depths of 10-20 cm (Callaham et al. 2001). *Lumbricus terrestris*, also called the dew worm, is a large anecic (deep dweller) species with a darkly pigmented anterior region that constructs deep vertical burrows to transport soil materials to and from deep depths of the soil profile. Only 2 species that occur at FONE are available for American woodcock foraging: *L. rubellus* and *L. terrestris*.

A total of 2,214 earthworms with a total biomass of 360.95 grams were collected from all shrub plots and open plots. *Eisenia rosea* comprised 41% of the total earthworms collected (Figure 8). *L. rubellus*, *O. tyrtaeum*, and *L. terrestris* comprised 9%, 44%, and 6% of the total captured. Figure 9 shows the average number of each worm species captured per square meter. We also examined the mean and standard error of soil variables and earthworms (number/square meter) associated with each shrub/tree species and in open spaces (Table 5).

Songbirds

We identified 33 bird species and 398 individual birds during our point counts (Table 6). Cedar waxwings (*Bombycilla cedrorum*) were the most numerous birds encountered, with 132 individuals recorded. Two bird species, the prairie warbler (*Dendroica discolor*) and golden-winged warbler (*Vermivora chrysoptera*) are birds of special concern; both species are listed as birds of conservation concern according to the US Fish & Wildlife Service (<http://migratorybirds.fws.gov/reports/bcc2002>) and are listed on the Audubon Watchlist

(<http://www.audubon.org/bird/watch>). None of the birds we encountered were new to the park (Yahner et al. 2004).

Small mammals

We captured 11 species of small mammals in 24,009 trap nights (Table 7). Common species include white-footed mice (*Peromyscus leucopus*), meadow jumping mice (*Zapus hudsonius*), meadow voles (*Microtus pennsylvanicus*), shorttail shrews (*Blarina brevicauda*), and masked shrews (*Sorex cinereus*). None of the species captured are labeled “rare” on the Pennsylvania Natural Heritage Program’s Rare Species List, though a few were new species to the park (Yahner et al. 2004) (see Appendix VIII for list of new FONE species identified during the project).

Amphibians and reptiles

Pitfall traps were open for a total of 576 trap nights. We caught 6 species of amphibians and 2 species of reptiles in the pitfall traps (Table 8). Small mammals captured include: masked shrew, shorttail shrew, smoky shrew (*Sorex fumeus*), meadow jumping mouse, meadow vole, and star-nosed mole (*Condylura cristata*). None of the species captured were state-listed species, though a few species were new park records (Appendix VII).

We conducted 432 flip-checks of the coverboards in 2004 and 2005 (number of coverboards (36) multiplied times the number of times they have been flipped over (12)). Vertebrates include: 28 redback salamanders (*Plethodon cinereus*), 1 eastern garter snake, and 6 eggs from a smooth green snake (*Opheodrys vernalis*). Four redback salamanders were caught in May 2004, 3 months after the coverboards were placed in the study area. Six redback

salamanders were detected under the coverboards in June 2004, 4 in August 2004, 9 in May 2005, 5 in June 2005, and 0 in July 2005.

Discussion

Total nonstructural carbohydrates

Total nonstructural carbohydrate levels fluctuated according to season and plant phenological stage, a phenomenon noted in other temperate shrub and tree species (Menke & Trlica 1981, Sosebee 1983, Loescher et al. 1990, Kozlowski 1992). At our study site, Morrow's honeysuckle was one of the first shrubs to leaf and flower and one of the last shrubs to undergo leaf senescence, a characteristic noted in other exotic bush honeysuckle species (Harrington et al. 1989a, Woods 1993). The best time to mechanically remove or cut Morrow's honeysuckle is in May, after the plant has leafed-out and started to flower (see Figure 1). The plant uses most of its carbohydrate reserves during this period and is less likely to resprout if mechanically removed or cut. Managers can maximize their efforts at controlling Morrow's honeysuckle if they time their control efforts to coincide when total nonstructural carbohydrate levels are at their lowest, immediately after leaf and flower formation.

Assessing Morrow's honeysuckle removal methods

Cut treatment and mechanical treatment of Morrow's honeysuckle was most successful in May, when TNC levels were at their lowest. We also found success of both stump and foliar application of glyphosate to be greater in May; however, previous studies reported that application of herbicide is most effective later in the growing season (Lynn et al. 1979, Nyboer 1992). Cutting the shrubs in May, when carbohydrate reserves were at their lowest, prevented

the plant from sprouting as vigorously than during September treatments, when carbohydrate reserves were higher. The application of glyphosate to the exposed stumps caused little additional mortality to shrubs; there were no significant differences in shrub cover, stem densities, or shrub densities between cut and stump treatments in May and between cut and stump treatments in September. Stump application of herbicide in September resulted in the greatest number of stems (a 342% increase from pre-treatment stem density); this was partly a reflection of the herbicide causing numerous stunted sprouts, or ‘witches brooms,’ on some of the stumps, a condition also noted on Amur honeysuckle stumps treated with glyphosate (Conover & Geiger 1993). Foliar application of herbicide may have had less success in September because of stress caused by the fungus *Insolibasidium deformans* (Auriculariaceae) (identification confirmed by W. MacDonald, West Virginia University, Morgantown). This blight, found only on *Lonicera*, causes a crinkling and browning of the leaves (Sinclair et al. 1987), a condition that may impact the uptake and subsequent translocation of the herbicide (Lynn et al. 1979). Morrow’s honeysuckle shrubs infected with this fungus became more common later in the growing season. However we also believe late-season timing for herbicide application of bush honeysuckles may be overstated. Hartman and McCarthy (2004) had $\geq 94\%$ stem mortality rates on Amur honeysuckle stems treated in March for both EZJect application of glyphosate pellets and stump application of glyphosate. We suspect our decreased rates of success for controlling Morrow’s honeysuckle relative to other bush honeysuckle removal studies relate to 1) the extremely high densities of shrubs at our study site and, 2) the open habitat in which shrubs at our study site were growing. Compared to Hartman and McCarthy (2004), we had nearly three times as many honeysuckle stems (176,000 vs. 65,959/ha) and shrubs (67,920 vs. 21,380/ha). These high densities may have prevented complete foliar

coverage of herbicide on smaller shrubs growing underneath the main canopies of the larger shrubs, making complete coverage difficult. Previous studies have noted increased vigor of exotic bush honeysuckles growing in areas exposed to full sunlight relative to those growing under forested canopies (Luken 1988, Harrington et al. 1989*a*, 1989*b*, Luken 1990, Luken & Mattimiro 1991, Luken et al. 1997). The increased carbohydrate reserves available to open-grown bush honeysuckle shrubs make complete eradication more difficult. For example, Luken (1990) reported that repeated clipping of Amur honeysuckle shrubs growing under a forest canopy killed 70% of shrubs, while the same treatment with shrubs growing in open canopies yielded only 10% mortality.

Overall, mechanical removal in May was the most effective method to reduce shrub cover, stem density, and shrub density. However, this treatment method required the most amount of labor and as a result, had the second highest costs. Trisel (1997) also found that prying Amur honeysuckle shrubs with a pulaski was a successful method (98% mortality), but was labor intensive. The least effective methods were cutting the shrubs in September and stump application of herbicide in September. Cutting in September only reduced plant densities by 13.8%, while stump application reduced shrub densities by 29.1%. Moreover, stump application of glyphosate was the most expensive method, since it not only took many hours of labor to cut the shrubs, but also required more herbicide (20% solution compared to 2% foliar solution). The labor required for stump application of herbicide (467 hrs/ha) was much greater than those from another study (170 hrs/ha) (Henderson 1981); this difference was probably a result of the greater number of stems that had to be treated within our study plots.

While differences in native shrub density among treatment method-month after removal were not statistically significant, there was a trend of decreasing native shrub densities following

treatments. All stump and foliar treatments of herbicide decreased native shrub density. Though we attempted to direct the herbicide spray towards Morrow's honeysuckle and away from native shrubs, some of the smaller, inconspicuous seedlings were inadvertently sprayed, leading to an overall decrease in native shrubs in these treatments. However, cut and mechanical treatments also showed signs of decreased native shrub numbers; this may be related to high white-tailed deer (*Odocoileus virginianus*) densities at Fort Necessity National Park (Yahner et al. 2004). We saw several native shrubs that showed signs of browse after being released from the dense thickets of Morrow's honeysuckle. Deer browsing might be responsible for an overall decrease in native shrub densities in treated plots; control plots had an overall increase in native shrub densities, possibly a result of the dense thickets of Morrow's honeysuckle limiting access to browsing deer. Though the shoots of exotic bush honeysuckles may confer some protection from deer browsing, other studies have shown that the shrubs have an overall negative effect on native woody species (Gorchov & Trisel 2003, Hartman & McCarthy 2004). The negative effects of overabundant deer herds in natural areas has been well-researched (e.g., Warren 1991, Stromayer & Warren 1997, Vellend 2002) and is a problem that will need to be addressed at Fort Necessity National Battlefield if post-eradication restoration efforts are to be successful.

Metrics of herbaceous community quality (i.e., richness, diversity, total cover, etc.) were maximized in mechanical and cut treatments performed in May. Plots treated in May had an extra growing season to recover and regenerate, compared to plots treated in September. Plots sprayed with herbicide had reduced metrics of herbaceous community quality, particularly foliar applications performed in September. Plants sprayed during this season are not yet dormant, so it is not surprising that the herbaceous community was reduced as a result of the herbicide. Trisel (1997) also noted a severe reduction of non-target herbaceous species when herbicide was

applied to Amur honeysuckle growing in a forest. To reduce mortality of understory species, other studies recommended spraying later in the year when understory plants were dormant, but the leaves of bush honeysuckle had not yet senesced (Nyboer 1992, Conover & Geiger 1993). We decided to perform eradication measures earlier to avoid possible early frosts which often occur in this mountainous region of Pennsylvania (C. Ranson 2004, Fort Necessity National Battlefield, Farmington, Pennsylvania, personal communication). However, unlike other treatments, foliar application of glyphosate in September reduced richness and percent cover of exotic herbaceous species.

From one-third to two-thirds of herbaceous cover in all treatments consisted of exotics. After treatments, new exotic species emerged, including aggressive invaders like tree of heaven and spotted ladythumb. Removing the honeysuckle shrubs created a void for other exotic invaders to colonize, making selection of the “best” treatment method troublesome. Although we tried a wide array of removal techniques, and some of the techniques were successful in reducing Morrow’s honeysuckle, none of the methods seemed to create conditions favorable for the establishment of native woody or herbaceous species. If restoration is to be successful, further post-eradication efforts, including deer control and planting of native seedlings and herbs, will have to be employed to shift current conditions so that they favor the long-term establishment and growth of natives.

American woodcock

Singing ground survey

American woodcock used a number of different sites as singing grounds in the study area. However, a few sites seemed to have more importance than others, particularly areas

located along the upper trail within the treatment area. These areas had open areas for the males to display and call, while also having protective cover nearby. The areas also seemed to have better acoustical qualities than other sites (personal observation); calls from these sites were distinctly heard from the Great Meadows below. Because of their high use by displaying male woodcock, the areas around the trail where woodcock were heard calling should be planted with dense native shrub cover if the honeysuckle is removed from the area. Dense plantings of trees should be avoided to maintain the scrub-shrub early successional habitat in these areas. If the area is eventually reforested, singing males would likely no longer use the site, since they prefer to display in open areas with little or no overstory (Dessecker & McGauley 2001).

Flush counts

Flush transects were not effective in determining woodcock abundance within the study area. Few birds were flushed while performing the surveys and those that were flushed were located directly on the trail. The security provided by the dense cover of shrubs along the transects may have made it more difficult to flush birds from their positions. It also is possible that the dense cover of shrubs is not ideal habitat for the woodcock; the dense thickets may be too difficult for woodcock to walk or fly through. By clearing a trail through the dense thickets of honeysuckle, we may have actually *enhanced* habitat for woodcock, making it easier for the birds to forage for invertebrates or fly in case of danger. We believe this latter explanation explains why nearly every woodcock we flushed was located directly on the trail where the dense overstory of Morrow's honeysuckle had been removed. Moreover, woodcock randomly flushed in the honeysuckle were typically located in areas of relatively sparse honeysuckle cover. We did not flush any woodcock in dense thickets of Morrow's honeysuckle.

We did not locate signs of American woodcock nesting or foraging in the study area. Woodcock typically nest in young to mid-age forests interspersed with openings (Keppie & Whiting 1994). It is possible that woodcock nested within the study area, though we did not locate any nests despite many hours spent at the site performing other aspects of the study. Woodcock generally forage in areas where the soil is moist enough to allow their specialized beak to penetrate the surface. Except for a few areas in the study area (i.e., the creek/riparian area separating the control and treatment sites and the “wetland” area), the soil in the study area may have been too dry and dense for the woodcock beak to penetrate.

Earthworms

Given that the earthworm species found at FONE each possess unique behavioral characteristics (i.e., epigeic, endogeic, or anecic soil dwellers), the parameters predictive of their presence also are unique for each species. The earthworm species that occur at shallow enough depths for the 59 – 77 mm American woodcock beak include *L. rubellus*, *L. terrestris*, and *E. rosea* (Keppi & Whiting 1994). These earthworm species were found in far greater abundances under tulip poplar than any other shrub. Morrow’s honeysuckle and black locust also had high numbers of these earthworm species. Removal of Morrow’s honeysuckle at FONE may decrease the number of earthworms, and thus the food supply of American woodcock; however, the desired earthworm species are also found under tulip poplar, and under black locust to a lesser amount. An important consideration is that the Morrow’s honeysuckle shrubs used in this study were single shrubs that were greater than 2 m away from other shrubs. Therefore, the dense clumps of honeysuckle, which characterize much of the upland areas at FONE, are not indicative of ideal earthworm habitat. Removal of the dense thickets of Morrow’s honeysuckle may not reduce the earthworm population. Southern arrowwood, a native shrub, was associated with

lower abundances of the 3 of 4 exotic earthworms and should be considered when restoring the site.

If Morrow's honeysuckle is removed from FONE, reforestation after the removal has a great potential to increase the number of earthworms, however, conifers are not recommended for the reforestation management option. The palatability of coniferous tree species (being highly acidic) results in few earthworms living under conifers (Dessecker and McGauley 2001). Based on limited exploratory samples in forested areas and under tulip poplar within FONE, earthworms will likely disperse and flourish among the young hardwoods. American woodcock will likely use the young hardwood stands though they are less likely to use the area as the hardwoods mature and the understory becomes sparse (Dessecker & McGauley 2001).

Open spaces with sparse shrubs indicate important vegetative structure for American woodcock at FONE. Stribling and Doerr (1985) reported that 75% of the American Woodcock they sampled used open pastures at night as their foraging ground for earthworms (earthworms made up 99% of the food ingested). Open areas at FONE had many *E. rosea* which are consumed by American woodcock, but a low average density of the other dietary staples, *L. rubellus* and *L. terrestris*. Some open areas with sparse shrub cover should be maintained by personnel at FONE because open spaces are also used by the males as singing display grounds in the spring (Dessecker & McGauley 2001).

Management of American woodcock at FONE

Overall, the study area serves as an important singing area for American woodcock and provides shelter for woodcock. To maximize American woodcock populations at FONE, it is necessary to maintain the important singing ground sites while at the same time maintaining early successional cover. A portion of the study area (the control area) should be maintained as

quality early successional habitat. Morrow's honeysuckle should be removed from this area, but care should be taken to ensure that native shrubs and trees remain. Infrequent mowing (every 2-3 years) or prescribed fire should be used to maintain the early successional habitat at FONE. Mowing should occur at the beginning of the growing season prior to woodcock nesting (end of March/first of April). Mowing at the beginning of the growing season ensures that adequate cover for woodcock and other wildlife is available not only during the summer months, but also the winter months. Mowing should not occur early in the growing season (i.e., May, June, or July); doing so jeopardizes the survival of nesting songbirds, fledglings, and newborn mammals such as fawns and eastern cottontails (*Sylvilagus floridanus*). It also reduces nectar sources and food plants for butterflies and other insect species. Unfortunately we saw untimely mowing occur in the Great Meadows and other open fields at FONE despite objections from natural resource managers. Poorly timed mowing regimes, coupled with infestations of Morrow's honeysuckle, are the likely reasons why various birds (i.e., American kestrel (*Falco sparverius*), bobolink (*Dolichonyx oryzivorus*), Henslow sparrow (*Ammodramus henslowii*), and savannah sparrow (*Passerculus sandwichensis*)) requiring quality early successional habitat have not been observed at FONE in many years (Yahner et al. 2004).

Prescribed fire is another tool that should be considered to maintain quality early successional habitat at FONE. Prior to European settlement, fire was often used by Native Americans to maintain early successional habitat for large herbivores and to facilitate the recruitment and growth of oaks and other important mast crops (Day 1953, Delcourt & Delcourt 1997, Cooley 2004). Burning would probably be the least expensive and most historically accurate method to maintain the early successional habitat at FONE; the study area is already laced with wide trails that would serve as adequate fire breaks. Burning should be performed in

early spring prior to the emergence of herbaceous species. The study area should be blocked into different burn units to avoid burning the entire area during the same year. Burning different units on a rotation of every 2-3 years ensures that adequate refugia are maintained for wildlife, particularly butterflies (R. Gatrell, lepidopterist, Charlestown, SC, personal communication).

Perhaps the management activity that would most benefit American woodcock would be to restore the wetlands within the Great Meadows. While restoration of the meadows is out of the scope of this project, it is clear that the wetlands within the Great Meadows have been degraded due to stream channelization, the construction of drainage channels, and the placement of fill in the area of the replica of Fort Necessity (Thomas & DeLaura 1996). Restoring these areas would simultaneously create more favorable habitat for American woodcock *and* fulfill the park's goals of restoring the historical landscape within the Great Meadows.

Songbirds

The study area supported a wide array of songbird species. In the short term, reforestation will benefit early successional bird species, such as eastern towhees (*Pipilo erythrophthalmus*) and song sparrows (*Melospiza melodia*). As the forest matures, more forest-dwelling species of birds, such as black-throated green warblers (*Dendroica virens*) and wood thrush (*Hylocichla mustelina*), will inhabit the study area. We recommend that a portion of the study area (the treatment area) be restored to a deciduous forest, while the remaining portion (the control and wetland area) be restored to quality early successional habitat. Maintaining the early successional habitat would continue to create habitat for prairie warblers and golden-winged warblers, two species of conservation concern that currently nest in the early successional scrub-shrub habitat in the study area. Maintaining early successional habitat in the absence of dense

thickets of Morrow's honeysuckle would also benefit other birds that depend on early successional habitat, such as American kestrel, Henslow's sparrow, savannah sparrow, and bobolink. Historical records indicate that these birds were once found in the park, but recent surveys failed to detect these early successional-grassland specialists (Yahner et al. 2004).

Small mammals

McShea et al. (2003) stated that the recolonization ability (post-timber harvesting) of most small mammals, particularly shrews, is unknown. Nevertheless, without previous studies on the recolonization of small mammals after honeysuckle removal, we can use other observational studies in various habitats to predict certain small mammal species that will prefer to inhabit the rehabilitated site given various management options.

If no action is taken to remove the Morrow's honeysuckle at FONE, the small mammal community can be expected to remain similar to what currently exists in the study area. Small mammal populations fluctuate by season and year (MacCracken et al. 1985); therefore, mild fluctuations in populations can be expected if the honeysuckle persists at FONE.

Removal of the honeysuckle to obtain an early successional habitat followed by either burning, infrequent mowing, or spot treatment will likely result in more meadow jumping mice; 46% of the meadow jumping mice were captured in the areas sparsely populated by honeysuckle (106 individuals in 'Zoo' and 'Field' out of 232 total individuals). Compared to the Morrow's honeysuckle, quality early successional habitat will produce a greater abundance and diversity of forbs and grasses and therefore, insects; this increase in herbaceous vegetation will provide the dietary requirements for many small mammals. Healy and Brooks (1988) caught the greatest number of small mammals in an early successional habitat where undergrowth, shrub cover, and vine cover were maximized.

White-footed mice were the most frequently encountered small mammal in every grid location. With an increased herbaceous layer and food supply, this generalist species' population is expected to increase or remain stable. Treatment of the honeysuckle with a glyphosate herbicide has been shown to have little or no effect on recruitment of *Peromyscus* and *Microtus* young (Sullivan 1990).

Vole populations typically decrease following removal of cover, as they are more vulnerable to predation and the food supply is reduced; however, the high reproductive potential enables voles to recover rapidly following removal of cover (Edge et al. 1995). Our data are consistent with Edge et al. (1995); one month after mowing, no meadow voles were caught in the 2 field areas; however, one year later in the same fields, 35 meadow voles were captured. Mowing causes a disruption in the social structure by causing individuals to abandon home ranges and territories (Edge et al. 1995). These data are further evidence that voles do not respond favorably in the short-term to mowing, though in the long-term, their high reproductive rate and high dispersal rate allows them to recover and disperse into other early successional habitat.

Shrews have been shown to increase in density and extend their breeding season with an abundance of food in the litter layer (*e.g.*, earthworms and gastropods in the spring, beetle and fly larvae in the fall) (McCay & Storm 1997). Shrew abundance and diversity also is positively related to ground moisture (McCay & Storm 1997); sparse shrub cover would help retain moisture and allow a diversity of herbs and invertebrates in the open spaces.

Amphibians and reptiles

The most common amphibian captured was the redback salamander. The redback salamander eats any palatable prey it can capture, with small invertebrates comprising the dietary

mainstay (Petranka 1998). A study by Pauley (1978) found that ants (Hymenoptera: Formicidae) were the primary prey in 86 adults from West Virginia. This study found that when a redback salamander was captured under a coverboard, ants also occurred under the same coverboard 28% of the time (5 joint occurrences out of 18 salamander occurrences).

Reforestation will benefit redback salamanders, as well as other terrestrial salamanders. Both adult and juvenile redback salamanders are often plentiful in well-drained forests (Petranka 1998). Leaf litter and decaying logs are beneficial for retaining moisture and provide optimum habitat requirements for terrestrial salamanders (Ash 1995, Petranka 1998). Brooks (1999) found that at the stand level, redback salamanders were positively correlated with coarse woody debris (CWD) and the density of tall (> 1 m) woody stems. Currently the study site lacks CWD and the litter layer is poorly developed. However, these conditions will slowly be ameliorated if reforestation occurs at the study site and the new forest is permitted to mature.

Although we only caught black rat snakes and a northern ring-necked snake (*Diadophis punctatus edwardsii*) in the pitfall traps, we encountered other snakes in the study area, including eastern garter snakes and smooth green snakes. Because northern ring-necked snakes are a woodland species that feed on salamanders, they will benefit if reforestations occurs within the study site. The other 3 species of snakes should thrive if quality early successional habitat is maintained within the study area (Conant & Collins 1998).

Management Options

This portion of the management plan lists several options for managing the study area, including a preferred management strategy. Pros and cons are listed for each of the options.

Option 1: No action

If no action is taken to eradicate Morrow's honeysuckle in the study area, the shrub-scrub habitat (dominated by the honeysuckle) will continue to persist. Recruitment of native hardwoods is virtually non-existent within the area; the shrubs shade-out and eventually out-compete most native woody species. The few hardwoods that have managed to reach sapling size are stunted due to heavy browsing by white-tailed deer. The diversity of herbs and ground-dwelling invertebrates will continue to be depressed by the presence of the honeysuckle.

Displaying woodcock will continue to use the site during the breeding period. The shrubs will continue to provide cover for woodcock, though if the shrubs continue to spread and grow, the thickets may become too dense for woodcock use. The shrubs will continue to provide suitable nesting habitat for some bird species, particularly prairie warblers and golden-wing warblers, 2 species of conservation concern. However, previous studies have shown that American robins nesting in Amur honeysuckle, a close relative of Morrow's honeysuckle, had higher rates of nest predation compared to American robins nesting in native shrubs and trees (Schmidt & Whelan 1999). The berries will continue to provide an abundant source of food for many frugivorous songbirds, particularly cedar waxwings. However, the importance of the berries may be overstated, as the fruit is high in sugars, but relatively low in lipids and protein (Witmer 1996). Moreover, few invertebrate herbivores feed on the shrubs compared to the closely related and native southern arrowwood, suggesting that the exotic shrubs may depress

insect recruitment, which may ultimately affect other wildlife species, such as songbird nestlings and fledglings that depend on insect protein for growth and development (J. Love, unpublished data).

In the short term, taking no action will cost the least amount of money. No funds will have to be spent to remove, reforest, or maintain the area. However, the site will continue to be a large source of seeds for the spread of Morrow's honeysuckle, possibly increasing costs for FONE, as well as private landowners, in the long run. Moreover, failing to eradicate Morrow's honeysuckle and restore the area to its historical ecological condition contradicts the park's own philosophy of "reestablishing the vegetative conditions that existed during the historical period whenever possible" (Fort Necessity National Battlefield 1991).

Option 2: Remove Morrow's honeysuckle and maintain entire study area as early successional habitat

Removing Morrow's honeysuckle from the study area and maintaining the area as early successional habitat (either by periodic mowing or prescribed fire) will create an environment similar to what existed prior to the mid-1980s, when the meadow was mowed periodically. Grasses and forbs would increase in both cover and diversity. Removing the honeysuckle would likely increase the abundance of 2 rare plants found in the study area: purple bluets and slender wheatgrass.

Maintaining the entire area as a meadow would benefit American woodcock; the area would continue to be used as a singing ground during the breeding season and the open habitat with scattered shrubs will provide adequate cover for the birds. Bird species that have been absent from the park, such as the American kestrel, savannah sparrow, Henslow's sparrow, and

bobolink, would likely return to the area. Cedar waxwings might decrease in abundance, because the berries of Morrow's honeysuckle would be greatly reduced in abundance. Prairie warblers and golden-winged warblers would continue to nest in the area, provided some scrub-shrub habitat consisting of southern arrowwood, sweet crabapple (*Malus coronaria*), and hawthorne (*Crataegus* spp.) were left intact. Ground-dwelling insects would increase in abundance (J. Love, unpublished data), providing an ample food source for wild turkey (*Meleagris gallopavo*) and ruffed grouse (*Bonasa umbellus*) poults, as well as other songbirds.

The small mammal community would remain similar to what currently exists, though there may be an increase in meadow jumping mice. Amphibians, particularly terrestrial salamanders, would continue to be uncommon in the study area since coarse woody debris, and a well-developed leaf litter layer will be sparse. The area will be suitable habitat for black rat snakes, smooth green snakes, and garter snakes.

Depending on which eradication method is used, costs of removing the honeysuckle could cost anywhere from \$10,500 (foliar application of herbicide) - \$131,600 (stump application of herbicide). Maintaining the area, through periodic mowing, prescribe fire, or spot treatment of emerging exotic invasive species, would also cost money. While the park would have reduced the quantity of exotic invasive shrubs, the historic landscape around the replica of Fort Necessity would still not be an accurate depiction of vegetative conditions that existed during the battle.

Option 3: Remove Morrow's honeysuckle and restore the entire site to a deciduous forest

Removing Morrow's honeysuckle and restoring the area to a deciduous hardwood forest will create conditions similar to what existed during George Washington's celebrated loss at Fort

Necessity. During the first several years, the vegetative community will continue to be dominated by exotic grasses and native goldenrods. Once the overstory becomes established and the trees reach maturity, the understory will most likely revert to an understory of ferns, bristly dewberry (*Rubus hispidus*), and other common woodland forbs. If the deer population remains overabundant, the understory will be relatively depauperate, consisting mainly of ferns such as eastern hay scented fern (*Dennstaedtia punctilobula*) and New York fern (*Thelypteris noveboracensis*). This condition already exists in much of the park (Appendix IX).

American woodcock would use the area the first several years after honeysuckle removal and the planting of saplings. However, as the forest matures, the site will be used less frequently by woodcock. The singing displays will become less common and eventually cease as the forested overstory becomes established. The lack of light in the overstory will lead to a decrease in the number of shrubs in the understory, making the area unsuitable for sheltering woodcock. Understory shrubs will be dramatically decreased if the deer herd remains at or above carrying capacity.

The community of bird species occupying the study area would slowly change-over as the forest matures. Early successional species, such as prairie warblers and golden-winged warblers, will give way to woodland specialists, such as black-throated green warblers and red-eyed vireos (*Vireo olivaceus*).

The small mammal community will shift as well. Meadow voles will become less common and meadow jumping mice will give way to woodland jumping mice. However, white-footed mice, deer mice, masked shrews, and shorttail shrews will continue to be common.

Terrestrial salamanders will benefit most from reforestation of the site. The accumulation of coarse woody debris and leaf litter, as well as a cooler, moister microclimate,

will create favorable environmental conditions for salamanders. Northern ring-necked snakes will become more common in the area, though black rat snakes, garter snakes, and especially smooth green snakes, will become less common.

Honeysuckle removal costs, plus the costs of purchasing and planting more seedlings and/or saplings, make this option the most expensive. It is important to point out that reforestation will probably not succeed unless the deer herd is kept out of the area. This would require either fencing to be placed around the perimeter of the study area or a sharp decrease in the number of deer within the park (either by hiring professional sharp-shooters or allowing limited hunting). Although this option would cost the most, it would also create the park's desired historical environmental conditions.

Option 4: Remove Morrow's honeysuckle and restore part of the study area to a deciduous hardwood forest, while maintaining the remaining area as quality early successional habitat (PREFERRED OPTION)

To meet the park's goals of both restoring the historical vegetative landscape *and* creating habitat for American woodcock, we recommend removing the honeysuckle and planting half the area (the treatment area) in native hardwoods, while maintaining the remainder of the study area (the control and wetland areas) as quality early successional habitat. Reforesting the treatment area, which can be seen from the Great Meadows and the replica of Fort Necessity, will eventually approximate the vegetative conditions that occurred during the 1754 battle (Kelso 1994). Once the trees are fully grown, the restored hillside will permit a more accurate interpretation of the battle that occurred over 250 years ago, when the French and Indians hid

behind the old-growth stand of trees on the hillside, firing at Washington and his troops within Fort Necessity.

While mechanical removal of Morrow's honeysuckle in May was the most effective method at reducing the shrub, it was also the most labor-intensive. For this reason, it is not practical to physically remove every shrub within the study area. However, there are approximately 2.75 ha where mechanical removal would be effective (Appendix X). This area is dominated by southern arrowwood and other native shrubs and trees. Morrow's honeysuckle, while still common, does not dominate the area. Most of the shrubs are large and should be able to be pulled-out with a tractor and chain or pried up with a pulaski. Mechanical removal would reduce the need to follow-up treatment with a native seed mix, although some seeds should still be scattered where the shrub originally stood to keep other exotics from colonizing the vacant area. We estimate total cost of this method to be ~ \$6,400, or roughly $\frac{1}{4}$ of the costs estimated from treatment study plots (i.e., $\$9,300 \times 2.75 \text{ ha} \times 0.25$). We believe this part of the study area is at least 25% less dense than our study plots.

The areas outside the 2.75 mechanical removal area should be treated with a foliar application of 2% glyphosate in October. This method did not completely eradicate the shrub (68% mortality); for this reason, the area should be bush-hogged the following year in May, immediately after leaf and flower formation. Cutting at this time of year will further decrease Morrow's honeysuckle and reduce the visual impact of standing dead shrubs during the growing season. Throughout the growing season, Morrow's honeysuckle and other exotic species should be spot-treated with glyphosate. We estimate the cost (not including bush-hogging in May) for treating this 11.85 ha of Morrow's honeysuckle to be ~ \$9,125 (\$2,490 for herbicide + \$6,635 labor). These labor costs might be decreased if a tractor/sprayer is used to spray the herbicide. If

adequate help from SCA or other volunteers are available, honeysuckle in the designated spray area can be removed by hand and/or with tractors. This method should be attempted in areas where high densities of native shrubs exist so that they will be spared from the herbicide application. There are relatively high densities of southern arrowwood along the lowest slope of the study area; other patches of native shrubs are scattered throughout the study area. These areas should be flagged prior to spraying.

Prior to planting native seeds and saplings, the site will need to be prepared the following fall (i.e., one year after removal methods have been carried out). Site preparation can be achieved by either burning or disking. If there is enough fine material (i.e., dried grasses, leaves, etc.) then fire would reduce the honeysuckle slash and prepare the site for planting. However, if there is not enough fine material or fire remains a non-obtainable option, the site should be disked and/or chipped. Fire should be performed later in the fall (November), when conditions are drier and less humid. Disking should be performed anytime in the fall.

Following site preparation (i.e., during the same season – fall), native grasses and forbs should be planted to reduce the opportunities for colonization of exotic invasive plants and to promote favorable early successional wildlife habitat. A list of species was developed specifically for the meadow with the aid of W. Grafton (West Virginia University, Morgantown) (Appendix XI). Most of the species are Pennsylvania ecotypes. For best germination, the seeds of these species should be planted in the fall.

Currently there are 308 saplings of 10 different species that occur in the park's nursery (Appendix XII). We recommend a planting of at least 1,683 saplings/ha (681 saplings/acre) placed at a spacing of 2.44×2.44 m ($8' \times 8'$), a recommendation echoed in earlier reports (Ranson 2003). To make the area appear more “natural”, the $8' \times 8'$ spacing should not be

systematic (i.e., the area shouldn't look like a plantation). Approximately 6.04 ha (14.92 acres) would be planted, for a total of ~ 10,160 saplings. To approximate conditions prior to clearing (Kelso 1994), the type and number of saplings to be planted should be: northern red oak (*Quercus rubra*; n = 2000), white oak (*Q. alba*; n = 2000), chestnut oak (*Q. prinus*; n = 1500), sugar maple (*Acer saccharum*; n = 1500), hickories (*Carya glabra* or *C. tomentosa*; n = 1000); white ash (*Fraxinus americana*; n = 1000), black cherry (n = 500), and red maple (n = 500). The majority of chestnut oak and hickories should be planted near the top of the slope, where conditions are drier. Fewer saplings would have to be planted if existing native shrubs and trees in the study area are left standing during the removal of Morrow's honeysuckle, though this may be difficult with a bush-hog. As mentioned earlier, these existing native species could be flagged prior to the treatment. Approximately 1,680 m of deer fencing would need to be erected around the reforested area; 880 m of fencing would need to be erected in the lower slope nearest the fort, while 800 m would need to be placed in the upper section near the nursery (Appendix XIII). If funds or lack of labor make it impossible to plant the entire treatment area, we recommend starting with the area most visible from the Great Meadows (see Figure 3), working upslope and then in a northwestern direction away from the replica of Fort Necessity.

The early successional habitat would need to be regularly maintained or Morrow's honeysuckle and other invasive species will once again dominate the site. We recommend burning the area every 2-5 years to kill emerging exotics and promote the continued establishment of warm season grasses and native forbs. The whole study site should not be burned all at once; instead, the site should be designated into blocks (this is already the case, as the trail system neatly divides the area into burn units) and burned on a rotational basis. Burning should be performed in early spring prior to herb emergence. If burning is not an option, the area

should be mowed ONCE a year during the early spring, prior to the herb/leaf emergence. Mowing at this time warms the ground for new native seeds; this mowing regime also provides cover and seed sources for wildlife in the winter. We also suggest mowing the different “units” on a rotational basis to provide refugia for wildlife and maintain a diversity of early successional habitat. Spot treatment of herbicide should be performed annually to kill emerging exotics before they spread.

For maintenance of the forested area, spot application of herbicide should be performed on an annual basis to kill emerging exotics before they spread. This cannot be overemphasized! If regular maintenance is not performed, the site will revert to a community dominated by Morrow’s honeysuckle and other exotics. All prior work will have been in vain! As the forest matures and bark thickens on the trees, we recommend burning on a 5-10 year basis. Burning promotes the establishment of oaks and prevents the spread of invasive woody species.

Early successional vegetation within the treatment area would slowly succeed to a woodland herb community. The control and wetland area would persist as quality early successional habitat, making it ideal for the persistence of 2 state-listed plants found in the study area (purple bluets and slender wheatgrass), species normally associated with old fields or prairies (Strausbaugh & Core 1977).

As canopy closure occurs in the treatment area, American woodcock would become less common. However the quality early successional habitat created in the control and wetland area would offset any losses in singing grounds or cover that was formerly provided in the newly forested area. Early successional bird species, such as the prairie warbler and golden-winged warbler, would continue to persist in the control and wetland area, while birds associated with woodland habitat would begin to occur in the reforested area.

Overall, the small mammal community would be little affected by the restoration. There would be a slight shift in species composition in the reforested area, but the areas maintained as quality early successional habitat would maintain a similar abundance and composition of species that are currently found in the study area.

The reforested area would eventually create ideal habitat for terrestrial salamanders and northern ring-necked snakes. The early successional habitat would continue to create suitable habitat for garter snakes, black rat snakes, and smooth green snakes.

Reforestation of the treatment area would cost less and require less labor than reforestation of the entire study area (10,160 saplings vs. 24,640 saplings). Though reforestation of the entire area would create conditions most similar to what existed 250 years ago, the control and wetland area cannot be seen from the Great Meadows where the battle occurred. Moreover, these areas did not play important roles during the battle, and therefore, have little importance in historical interpretation (i.e., movement of troops, troop positions, etc.) (Thomas & DeLaura 1996).

Conclusion

The degraded meadow dominated by Morrow's honeysuckle at Fort Necessity National Battlefield harbors a wide array of flora and fauna. However, diversity of both plants and wildlife can be augmented if the shrubs are removed. We recommend removing the honeysuckle throughout the entire study area, reforestation of the area adjacent to the Great Meadows, and maintaining the remainder of the study area as quality early successional habitat. This option accomplishes the park's dual goal of restoring the historical landscape adjacent the Great Meadows, while at the same time improving habitat for declining wildlife species, most notably the American woodcock.

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Tables

Table 1. Mean ($\pm$ SE) Morrow's honeysuckle post-treatment cover, stem density, and shrub density differed among treatment method-month at Fort Necessity National Battlefield. Means with different letters are significantly different ($p < 0.05$), based on Duncan's multiple range tests. Percent change (% Δ) represents percent change from mean pre-treatment condition.

<i>Treatment/Month</i>	<i>n</i>	<i>Cover</i>		<i>Stem density</i>		<i>Shrub density</i>	
		$\bar{X} \pm SE$	% Δ	$\bar{X} \pm SE$	% Δ	$\bar{X} \pm SE$	% Δ
Control/Sept.	2	1.00 (a) $\pm$ 0.00	+ 5.3%	528 (b) $\pm$ 104	+ 25.1%	211 (a) $\pm$ 32	+ 9.9%
Control/May	3	0.84 (b) $\pm$ 0.06	+ 9.1%	444 (b) $\pm$ 79	+ 36.6%	151 (a, b) $\pm$ 30	+ 20.8%
Cut/Sept.	5	0.48 (c) $\pm$ 0.14	- 43.5%	1,503 (a) $\pm$ 180	+ 233.3%	150 (a, b) $\pm$ 24	- 13.8%
Stump/Sept.	5	0.41 (c, d) $\pm$ 0.08	- 51.8%	2,302 (a) $\pm$ 210	+ 341.8%	141 (b, c) $\pm$ 22	- 29.1%
Foliar/May	5	0.17 (d, e) $\pm$ 0.06	- 75.7%	200 (c) $\pm$ 64	- 49.4%	49 (e) $\pm$ 17	- 66.4%
Cut/May	5	0.05 (e, f) $\pm$ 0.01	- 94.1%	422 (b) $\pm$ 56	+ 1.7%	92 (c, d) $\pm$ 8	- 39.9%
Mechanical/Sept.	5	0.05 (e, f) $\pm$ 0.01	- 94.0%	366 (b, c) $\pm$ 90	+ 9.6%	95 (c, d) $\pm$ 17	- 24.0%
Foliar/Sept.	5	0.04 (e, f) $\pm$ 0.01	- 95.8%	368 (b, c) $\pm$ 96	- 38.0%	85 (d) $\pm$ 12	- 68.8%
Stump/May	5	0.04 (e, f) $\pm$ 0.02	- 94.7%	390 (b, c) $\pm$ 184	- 11.0%	77 (d, e) $\pm$ 32	- 47.3%
Mechanical/May	5	0.01 (f) $\pm$ 0.01	- 98.7%	33 (d) $\pm$ 9	- 92.9%	14 (f) $\pm$ 4	- 91.3%

Table 2. Mean ($\pm$ SE) native shrub density among treatment method-month did not significantly differ prior to the removal of Morrow's honeysuckle or following removal of Morrow's honeysuckle in 45 5×5 -m plots at Fort Necessity National Battlefield. Percent change (% Δ) represents percent change from mean pre-treatment condition.

<i>Treatment/Month</i>	<i>n</i>	<i>Pre-treatment</i>	<i>Post-treatment</i>	% Δ
		$\bar{X} \pm SE$	$\bar{X} \pm SE$	
Control/May	3	16.7 $\pm$ 7.1	42.7 $\pm$ 10.2	+ 155.7%
Control/Sept.	2	28.0 $\pm$ 23.0	28.5 $\pm$ 16.5	+ 1.8 %
Cut/May	5	20.4 $\pm$ 2.7	29.8 $\pm$ 9.6	+ 46.1%
Cut/Sept.	5	28.8 $\pm$ 6.5	22.6 $\pm$ 3.2	- 21.5%
Foliar/May	5	19.0 $\pm$ 4.8	8.2 $\pm$ 1.0	- 56.8%
Foliar/Sept.	5	22.2 $\pm$ 7.7	21.0 $\pm$ 6.5	- 5.4%
Mechanical/May	5	37.8 $\pm$ 10.3	23.4 $\pm$ 5.3	- 38.1%
Mechanical/Sept.	5	13.6 $\pm$ 3.3	16.2 $\pm$ 4.4	+ 19.1%
Stump/May	5	25.2 $\pm$ 8.1	16.0 $\pm$ 2.6	- 36.5%
Stump/Sept.	5	22.0 $\pm$ 6.1	10.0 $\pm$ 2.4	- 54.5%

Table 3. Foliar application of herbicide was the cheapest treatment method, while stump application of herbicide was the most expensive method to control Morrow's honeysuckle growing in a degraded meadow at Fort Necessity National Battlefield.

<i>Treatment</i>	<i>Labor hrs./ha</i> $\bar{X} \pm SE$	<i>Labor cost/ha</i> ¹ $\bar{X} \pm SE$	<i>Equipment cost/ha</i> ² $\bar{X} \pm SE$	<i>Total cost/ha</i> $\bar{X} \pm SE$
Mechanical	933 ± 81	\$9330 ± \$810	\$0	\$9330 ± \$810
Cut	450 ± 35	\$4500 ± \$350	\$380 ± \$40	\$4880 ± \$370
Stump	467 ± 30	\$4670 ± \$300	\$4950 ± \$30	\$9620 ± \$330
Foliar	56 ± 5	\$560 ± \$50	\$210 ± \$20	\$770 ± \$60

¹Based on pay of \$10/hr.

² Based on: 2.5 gal of Roundup Pro = \$158; 1 gal bar oil = \$6.95; 1 gal mixed gas = \$2.75. Cost does not include sprayer, chainsaw, safety equipment, tools, or repair/maintenance costs.

Table 4. Post-treatment mean ($\pm$ SE) herbaceous measurements for 45 5 $\times$ 5-m plots under different seasons and treatments were recorded at Fort Necessity National Battlefield, Pennsylvania, U.S.A. in July 2005.

<i>Season-treatment*</i>	<i>n</i>	<i>Total cover (%)</i> $\bar{X} \pm SE$	<i>Native cover (%)</i> $\bar{X} \pm SE$	<i>Exotic cover (%)</i> $\bar{X} \pm SE$	<i>Total richness</i> $\bar{X} \pm SE$	<i>Native richness</i> $\bar{X} \pm SE$	<i>Exotic richness</i> $\bar{X} \pm SE$	<i>Diversity (H')</i> $\bar{X} \pm SE$	<i>Evenness (J')</i> $\bar{X} \pm SE$	<i>Mean C</i> $\bar{X} \pm SE$	<i>FQI</i> $\bar{X} \pm SE$
Spring-Control	3	35.7 $\pm$ 4.3 EF	21.9 $\pm$ 3.1 BC	13.8 $\pm$ 1.3 D	18.3 $\pm$ 1.2 BCD	9.9 $\pm$ 0.5 B	8.4 $\pm$ 0.7 ABC	2.45 $\pm$ 0.04 BCD	0.85 $\pm$ 0.03 AB	3.83 $\pm$ 0.15	11.8 $\pm$ 0.6 B
Autumn-Control	2	24.2 $\pm$ 0.4 GF	12.2 $\pm$ 0.4 C	12.0 $\pm$ 0.1 D	16.0 $\pm$ 0.2 BCD	8.5 $\pm$ 0.5 BC	7.5 $\pm$ 0.3 BC	2.36 $\pm$ 0.08 CD	0.86 $\pm$ 0.03 A	3.90 $\pm$ 0.01	11.3 $\pm$ 0.4 B
Spring-Cut	5	68.8 $\pm$ 3.8 A	42.3 $\pm$ 3.5 A	26.4 $\pm$ 2.6 BC	23.3 $\pm$ 1.6 A	13.6 $\pm$ 1.2 A	9.7 $\pm$ 0.6 AB	2.69 $\pm$ 0.07 AB	0.86 $\pm$ 0.02 A	3.98 $\pm$ 0.07	14.5 $\pm$ 0.5 A
Autumn-Cut	5	64.3 $\pm$ 4.0 AB	20.3 $\pm$ 3.2 C	44.0 $\pm$ 5.6 A	19.3 $\pm$ 1.2 BC	9.7 $\pm$ 0.8 B	9.6 $\pm$ 0.9 AB	2.12 $\pm$ 0.21 DE	0.71 $\pm$ 0.06 CD	3.80 $\pm$ 0.06	11.6 $\pm$ 0.5 B
Spring-Foliar	5	38.4 $\pm$ 3.0 DE	20.6 $\pm$ 3.2 C	17.8 $\pm$ 1.4 CD	15.2 $\pm$ 1.0 D	8.4 $\pm$ 0.6 BC	6.8 $\pm$ 0.5 C	2.24 $\pm$ 0.09 CDE	0.83 $\pm$ 0.02 AB	3.78 $\pm$ 0.09	10.8 $\pm$ 0.2 BC
Autumn-Foliar	5	19.3 $\pm$ 2.6 G	12.8 $\pm$ 2.9 C	6.5 $\pm$ 1.2 E	11.5 $\pm$ 1.0 E	6.7 $\pm$ 0.6 C	4.8 $\pm$ 0.6 D	1.87 $\pm$ 0.14 EF	0.77 $\pm$ 0.04 BC	3.86 $\pm$ 0.04	9.8 $\pm$ 0.3 C
Spring-Mechanical	5	61.4 $\pm$ 5.1 AB	38.9 $\pm$ 3.9 A	22.5 $\pm$ 3.2 C	23.5 $\pm$ 1.5 A	13.9 $\pm$ 0.9 A	9.6 $\pm$ 0.8 AB	2.77 $\pm$ 0.06 A	0.88 $\pm$ 0.01 A	3.72 $\pm$ 0.05	13.8 $\pm$ 0.4 A
Autumn-Mechanical	5	46.9 $\pm$ 2.1 CDE	21.0 $\pm$ 2.2 C	25.9 $\pm$ 1.4 BC	20.0 $\pm$ 0.5 AB	9.4 $\pm$ 0.5 B	10.6 $\pm$ 0.5 A	2.52 $\pm$ 0.05 ABC	0.85 $\pm$ 0.01 AB	3.77 $\pm$ 0.16	11.5 $\pm$ 0.4 B
Spring-Stump	5	57.3 $\pm$ 7.5 ABC	34.1 $\pm$ 6.1 AB	23.3 $\pm$ 1.9 C	18.3 $\pm$ 1.0 BCD	10.1 $\pm$ 0.6 B	8.2 $\pm$ 0.5 BC	2.40 $\pm$ 0.03 BCD	0.83 $\pm$ 0.02 AB	3.74 $\pm$ 0.05	11.8 $\pm$ 0.3 B
Autumn-Stump	5	50.6 $\pm$ 3.0 BCD	14.4 $\pm$ 2.6 C	36.2 $\pm$ 4.8 AB	15.4 $\pm$ 1.2 CD	8.2 $\pm$ 0.6 BC	7.1 $\pm$ 0.6 C	1.74 $\pm$ 0.16 F	0.63 $\pm$ 0.05 D	3.94 $\pm$ 0.06	11.2 $\pm$ 0.5 BC

* Means in columns with different letters are significantly different ($p < 0.05$), based on Duncan's multiple range tests.

Table 5. Means and standard errors of soil variables and earthworms (number/square meter) associated with each shrub/tree species and in open spaces at Fort Necessity National Battlefield from plots in August 2004 and May 2005.

Variable	Shrub Species ^a									
	<i>Lonicera morrowii</i> (n = 30)		<i>Liriodendron tulipifera</i> (n = 20)		<i>Open Spaces</i> (n = 29)		<i>Robinia pseudoacacia</i> (n = 20)		<i>Viburnum dentatum</i> (n = 29)	
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Soil Nutrient^b										
C	4.98	0.26	5.41	0.36	4.95	0.22	5.79	0.36	5.03	0.16
P	13.60	0.70	10.95	0.71	11.69	0.58	13.10	0.82	12.69	0.78
C/N	0.05	0.00	0.05	0.00	0.05	0.00	0.06	0.00	0.05	0.00
SM	22.28	0.76	24.99	0.79	22.40	1.10	23.61	0.86	23.53	0.54
pH	5.30	0.04	5.44	0.15	5.35	0.06	5.14	0.13	5.22	0.04
N	96.80	1.87	99.80	2.32	97.07	1.58	102.50	2.23	98.48	1.26
K	80.77	5.08	97.55	7.67	67.03	5.08	99.50	13.43	71.41	3.58
Worm Species^c										
<i>Eisenia rosea</i>	13.23	5.22	91.70	46.02	23.55	8.88	40.35	13.06	36.79	15.18
<i>Lumbricus rubellus</i>	11.43	3.01	23.20	11.13	2.86	1.58	11.65	4.13	2.86	1.25
<i>Lumbricus terrestris</i>	4.13	1.76	4.80	2.48	2.86	1.58	1.40	0.96	0.48	0.48
<i>Octolasion tyrtaeum</i>	27.83	6.46	25.30	10.62	31.10	8.36	34.90	10.62	27.79	8.29

^a Sample size represents 2 months soil nutrients were analyzed, not entire 6 months of worm collection.

^b C = carbon (soil organic matter; % of organic matter in the soil); P = phosphorus (parts per million [ppm]); C/N = carbon (soil organic matter): N = nitrogen (estimated nitrogen upon release) ratio; SM = soil moisture (% from $[(\text{wet weight} - \text{dry weight})/\text{wet weight}] \times 100$); pH = pH (H₂O 1:1); K = potassium (ppm).

^c Total worms counted in all plots (N = 128): *Eisenia rosea*, n = 350 worms; *Lumbricus rubellus*, n = 88 worms; *Lumbricus terrestris*, n = 25 worms; *Octolasion tyrtaeum*, n = 274 worms.

Table 6. Thirty-three bird species were identified during point count surveys within the degraded meadow at Fort Necessity National Battlefield; the surveys were performed once a month from March 2004 – February 2005.

<i>Species</i>	<i>Control</i>	<i>Treatment</i>	<i>Habitat Use</i>	<i>Total</i>
Canada goose <i>Branta canadensis</i>	0	7	Flyover	7
Sharp-shinned hawk <i>Accipiter striatus</i>	1	0	Flyover	1
Turkey vulture <i>Cathartes aura</i>	1	0	Flyover	1
Yellow-billed cuckoo <i>Coccyzus americanus</i>	0	1	Edge	1
Ruby-throated hummingbird <i>Archilochus colubris</i>	6	3	Nesting	9
Northern “yellow-shafted” flicker <i>Colaptes auratus</i>	1	1	Flyover	2
Barn swallow <i>Hirundo rustica</i>	2	4	Flyover	6
American crow <i>Corvus brachyrhynchos</i>	0	4	Flyover	4
Common raven <i>Corvus corax</i>	1	0	Flyover	1
Black-capped chickadee <i>Poecile atricapillus</i>	8	9	Foraging	17
Brown thrasher <i>Toxostoma rufum</i>	4	1	Nesting	5
Gray catbird <i>Dumetella carolinensis</i>	5	5	Nesting	10
Northern mockingbird <i>Mimus polyglottos</i>	0	1	Edge	1
American robin <i>Turdus migratorius</i>	2	4	Edge	6
Cedar waxwing <i>Bombycilla cedrorum</i>	32	100	Foraging/ Flyover	132
Red-eyed vireo <i>Vireo olivaceus</i>	0	2	Edge	2
White-eyed vireo <i>Vireo griseus</i>	2	0	Edge	2
Magnolia warbler <i>Dendroica magnolia</i>	1	0	Edge (conifers)	1
Chestnut-sided warbler <i>Dendroica pensylvanica</i>	8	5	Edge	13

Table 6. Continued.

<i>Species</i>	<i>Control</i>	<i>Treatment</i>	<i>Habitat Use</i>	<i>Total</i>
Prairie warbler <i>Dendroica discolor</i>	3	8	Nesting	11
Golden-winged warbler <i>Vermivora chrysoptera</i>	1	0	Nesting	1
Common yellowthroat <i>Geothlypis trichas</i>	12	8	Nesting	20
Common grackle <i>Quiscalus quiscula</i>	3	1	Flyover/ Edge	4
European starling <i>Sturnus vulgaris</i>	4	0	Flyover	4
Scarlet tanager <i>Piranga olivacea</i>	0	1	Edge	1
Northern cardinal <i>Cardinalis cardinalis</i>	3	1	Edge/ Foraging	4
American goldfinch <i>Carduelis tristis</i>	18	6	Edge/ Flyover	24
Indigo bunting <i>Passerina cyanea</i>	8	6	Edge	14
Eastern towhee <i>Pipilo erythrophthalmus</i>	13	12	Nesting	25
Chipping sparrow <i>Spizella passerina</i>	0	2	Edge	2
Field sparrow <i>Spizella pusilla</i>	20	13	Nesting	33
Song sparrow <i>Melospiza melodia</i>	1	2	Nesting	3
Dark-eyed junco <i>Junco hyemalis</i>	1	0	Interior (winter)	1
Unknown	19	11	Various	30
TOTAL: 33	180	218	-	398

Table 7. We captured 11 species of small mammals at FONE using Sherman live traps. The grids Nursery and Fort were included in the “treatment” area, while Zoo and Upland are included in the “control” area. The grids included in Forest and Field lie outside the study area.

<i>Species</i>	<i>Treatment</i>		<i>Control</i>		<i>Other</i>		<i>Total</i>
	<i>Fort</i>	<i>Nursery</i>	<i>Zoo</i>	<i>Upland</i>	<i>Forest</i>	<i>Field</i>	
White-footed mouse <i>Peromyscus leucopus</i>	166	154	74	68	85	49	596
Deer mouse <i>Peromyscus maniculatus</i>	0	1	0	0	3	2	6
Meadow vole <i>Microtus pennsylvanicus</i>	0	21	26	42	0	35	124
Southern bog lemming <i>Synaptomys cooperi</i>	0	0	2	0	0	0	2
Meadow jumping mouse <i>Zapus hudsonius</i>	38	43	97	43	2	9	232
Woodland jumping mouse <i>Napaeozapus insignis</i>	0	0	0	0	5	2	7
Shorttail shrew <i>Blarina brevicauda</i>	14	25	18	21	2	3	83
Masked shrew <i>Sorex cinereus</i>	13	21	43	9	2	1	89
Southern flying squirrel <i>Glaucomys volans</i>	0	0	0	0	1	0	1
Eastern chipmunk <i>Tamias striatus</i>	0	0	6	1	0	0	7
Red squirrel <i>Tamiasciurus hudsonicus</i>	1	0	0	0	0	0	1
Total	232	265	266	184	100	101	1,148

Table 8. We caught 6 species of amphibians and 2 species of reptiles in the pitfall trap arrays within the study area at Fort Necessity National Battlefield during the summer of 2004 and 2005.

<i>Species</i>	<i>No. Captures</i>	
	<i>Treatment</i>	<i>Control</i>
<u>Amphibians</u>		
Redback salamander <i>Plethodon cinereus</i>	1	3
Northern slimy salamander <i>Plethodon glutinosus</i>	0	1
Northern spring salamander <i>Gyrinopholis p. porphoriticus</i>	0	1
Red eft <i>Notophthalmus v. viridescens</i>	2	1
Wood frog <i>Rana sylvatica</i>	0	2
American toad <i>Bufo americanus</i>	0	2
Fowler's toad <i>Bufo woodhousii fowleri</i>	3	1
<u>Reptiles</u>		
Northern ring-necked snake <i>Diadophis punctatus edwardsii</i>	0	1
Black rat snake <i>Elaphe o. obsoleta</i>	1	0
TOTAL	7	12

Figures

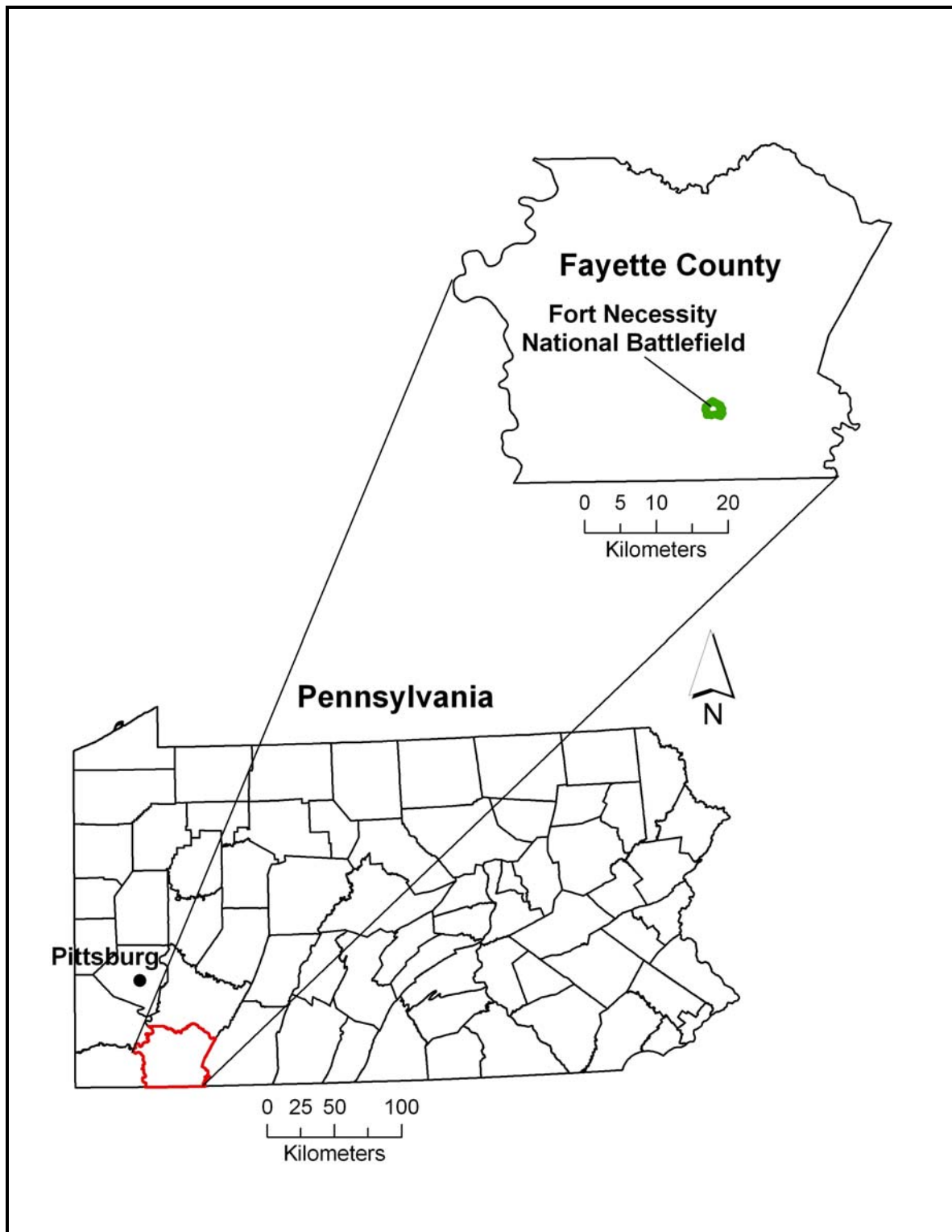


Figure 1. Fort Necessity National Battlefield lies in Fayette County, southwestern Pennsylvania.

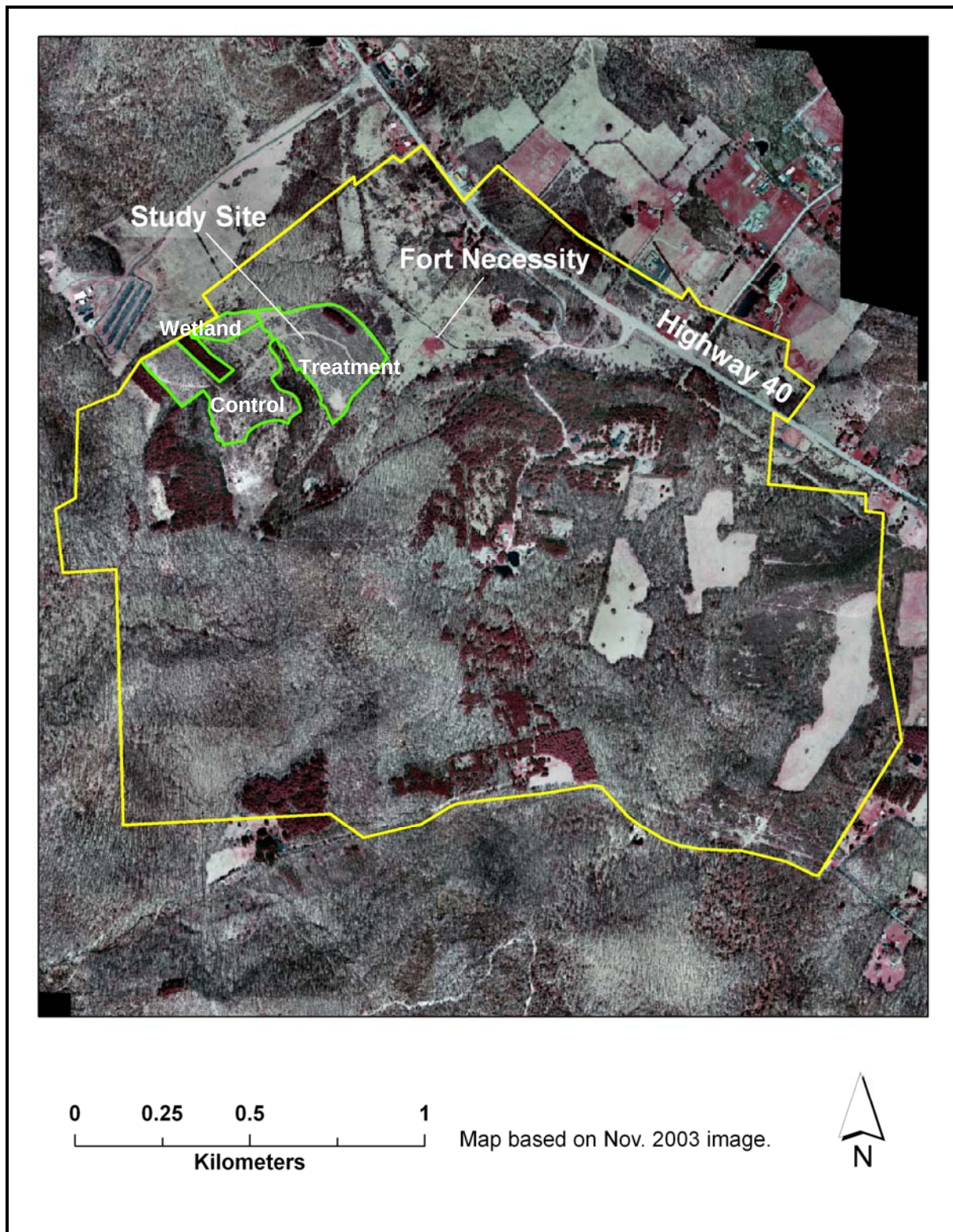


Figure 2. The study site is located within the 350.5 ha Fort Necessity National Battlefield. The site lies adjacent to the replica of Fort Necessity, the central historical attraction at the park.

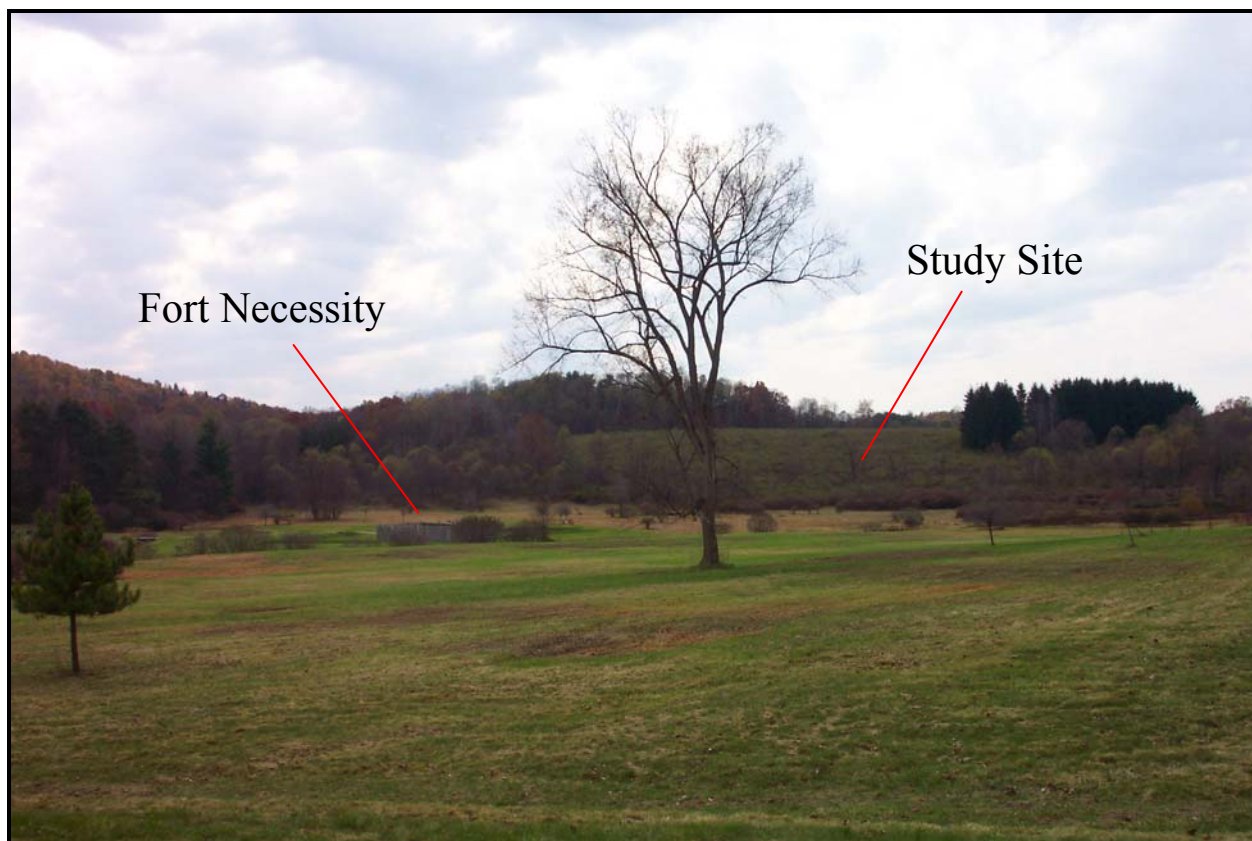


Figure 3. The study site overlooks the replica of Fort Necessity. Morrow's honeysuckle dominates the study site and has impeded natural regeneration of the hardwood forest.

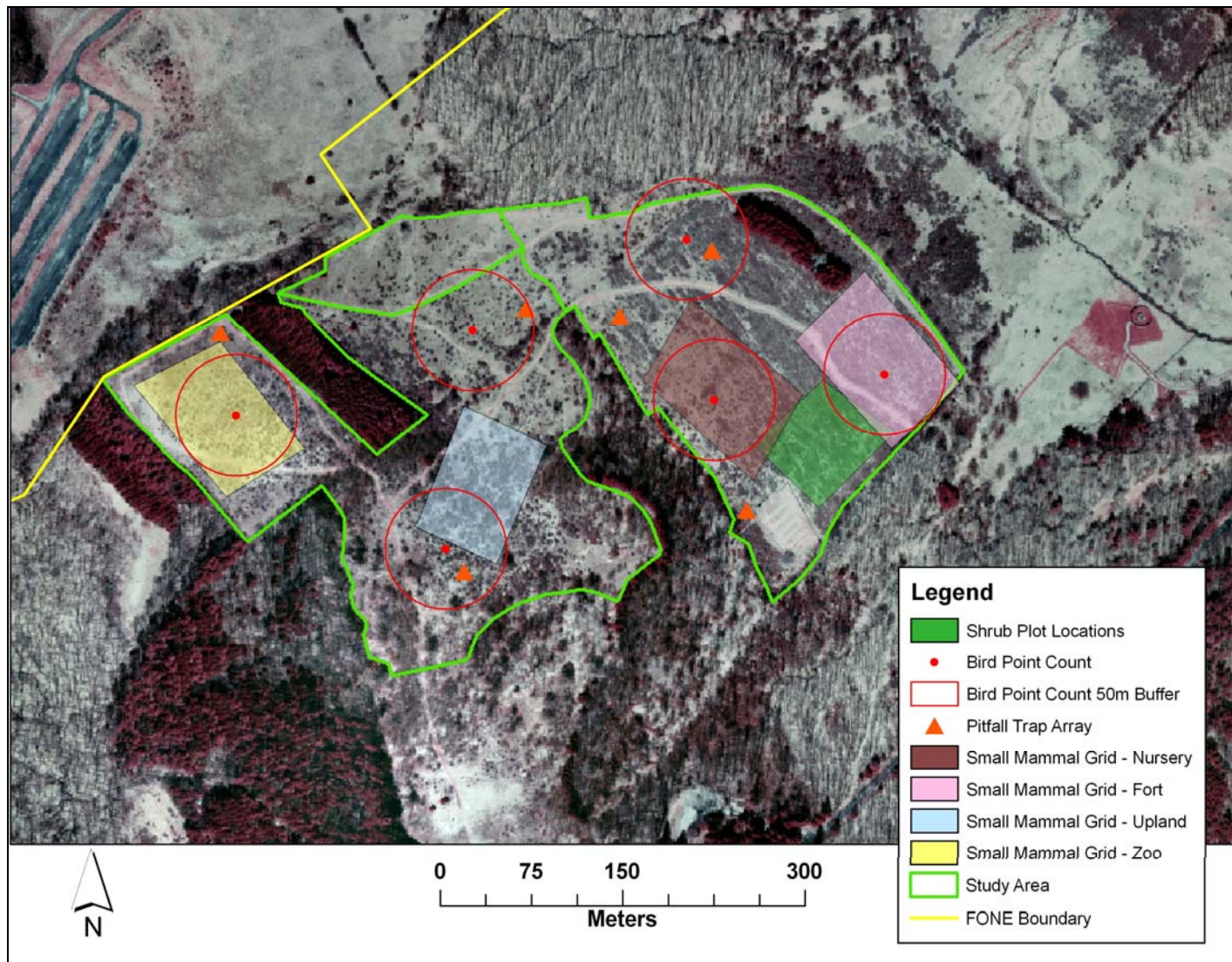


Figure 4. The study area at Fort Necessity National Battlefield includes an area set aside to test Morrow's honeysuckle removal methods, 6 bird point count locations, 6 pitfall trap arrays, and 4 small mammal grids.

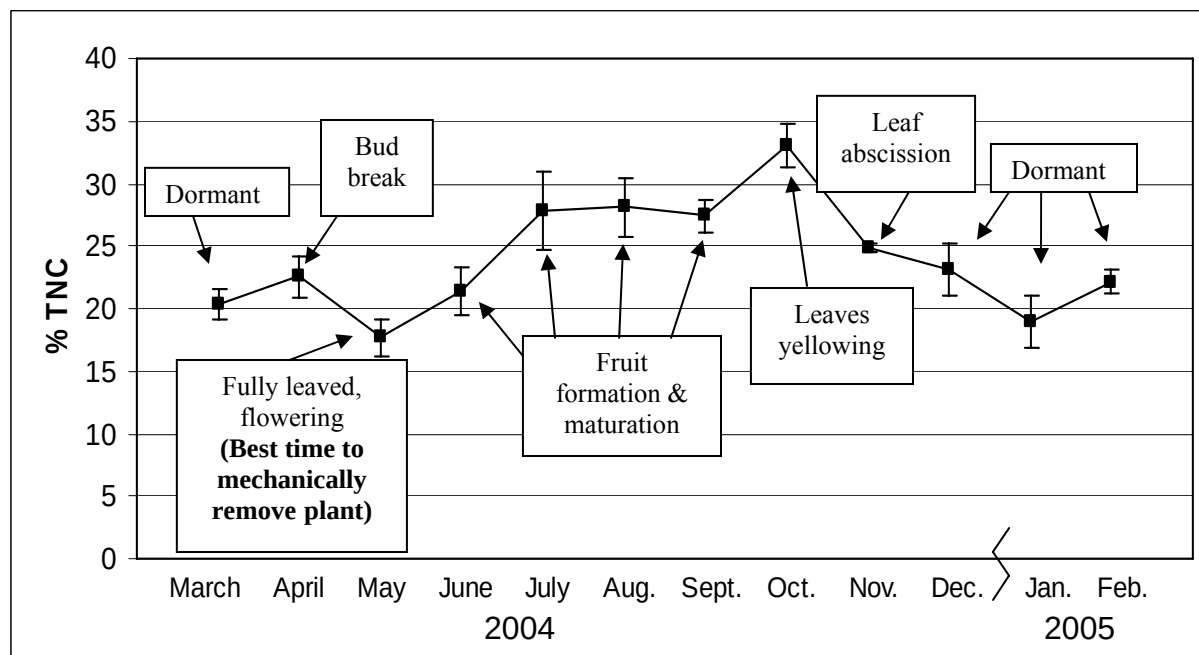


Figure 5. Total nonstructural carbohydrates were lowest in May and highest in October.

Consequently, the best time to mechanically remove the plant is in May after leaf-out. Bars are standard error bars.

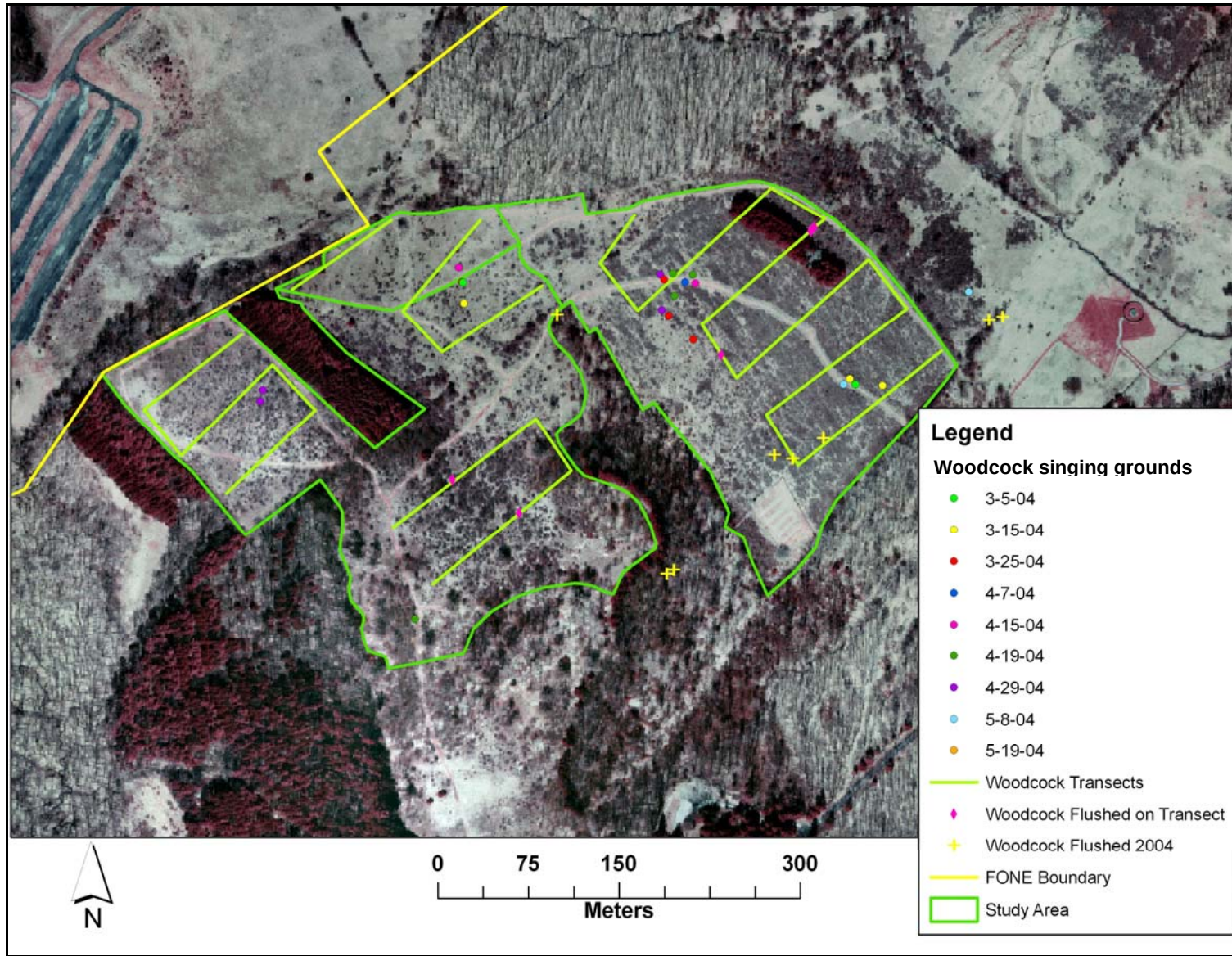


Figure 6. We mapped 18 American woodcock singing grounds from March 2004 – May 2004 at Fort Necessity National Battlefield.

We flushed 5 woodcock from the woodcock flush transects and randomly flushed 8 woodcock.

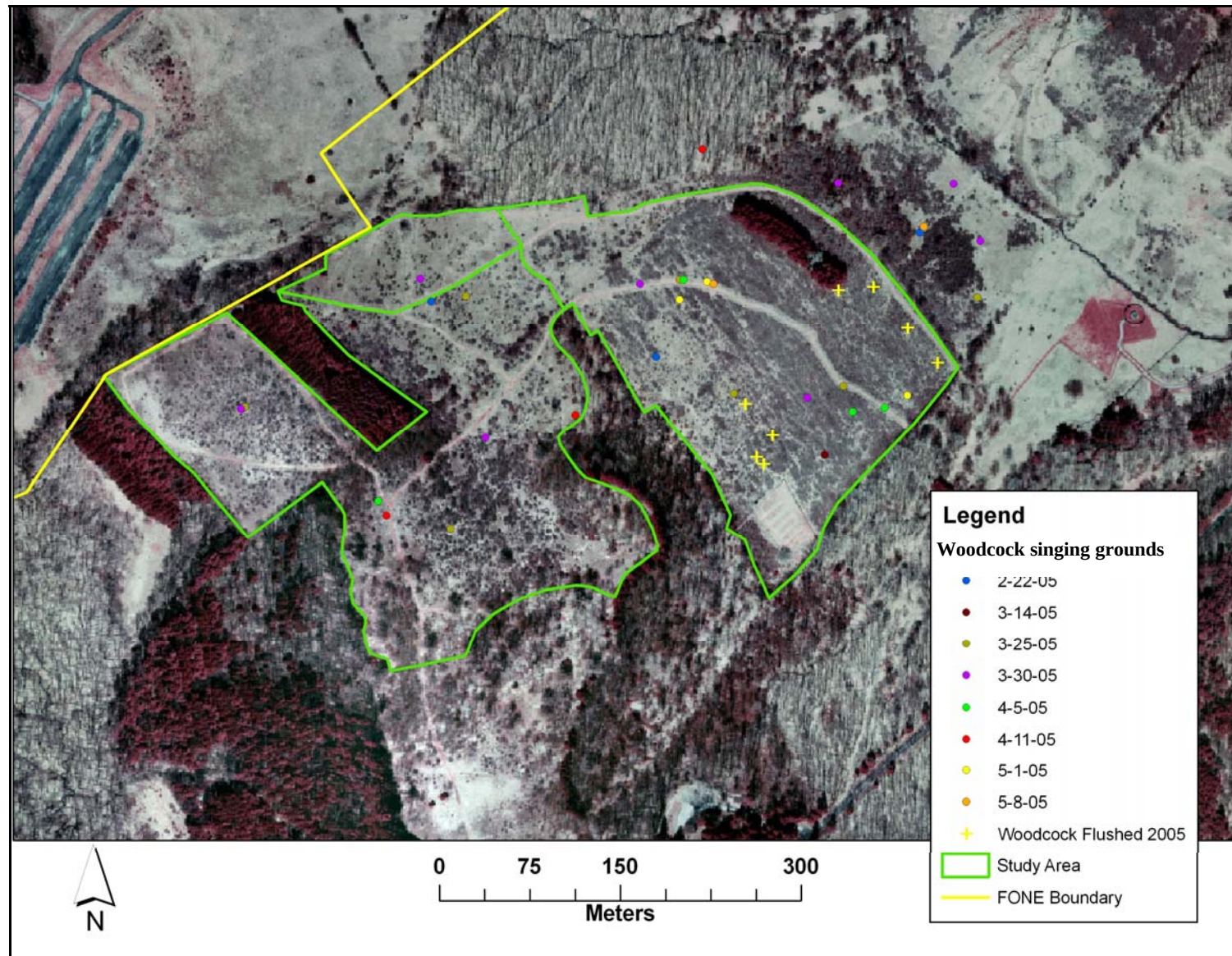


Figure 7. We mapped 31 American woodcock singing grounds from February 2005 – May 2005 at Fort Necessity National Battlefield. Moreover, we randomly flushed 8 woodcock in the study area.

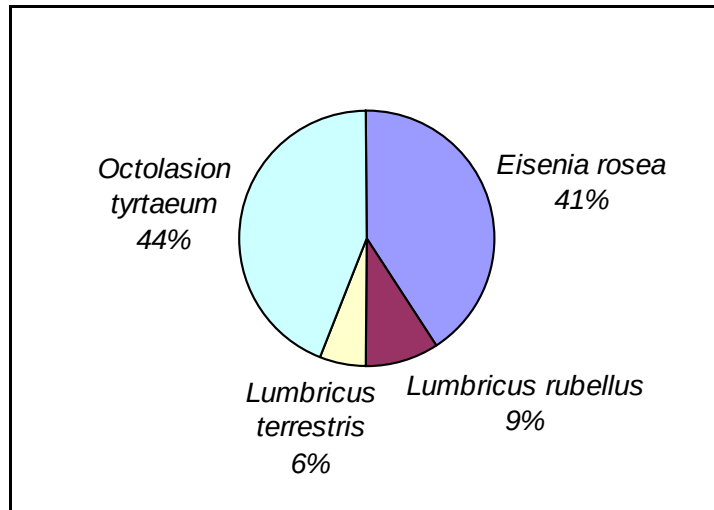


Figure 8. Percentage of each earthworm species collected from all plots at Fort Necessity National Battlefield from 2004 – 2005. N = 290 plots; total worms = 1,459 individuals.

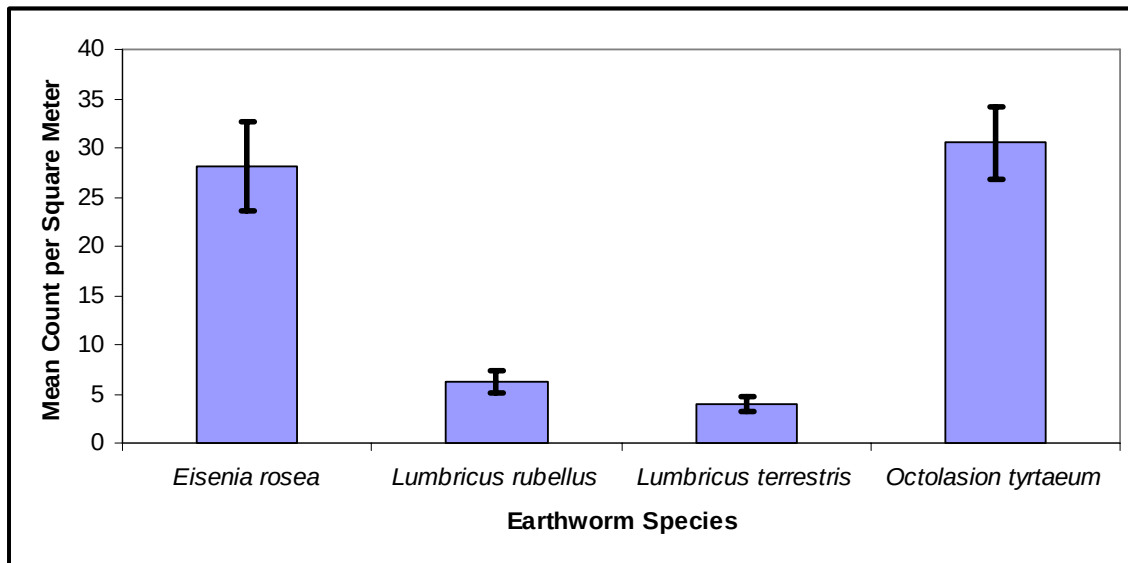
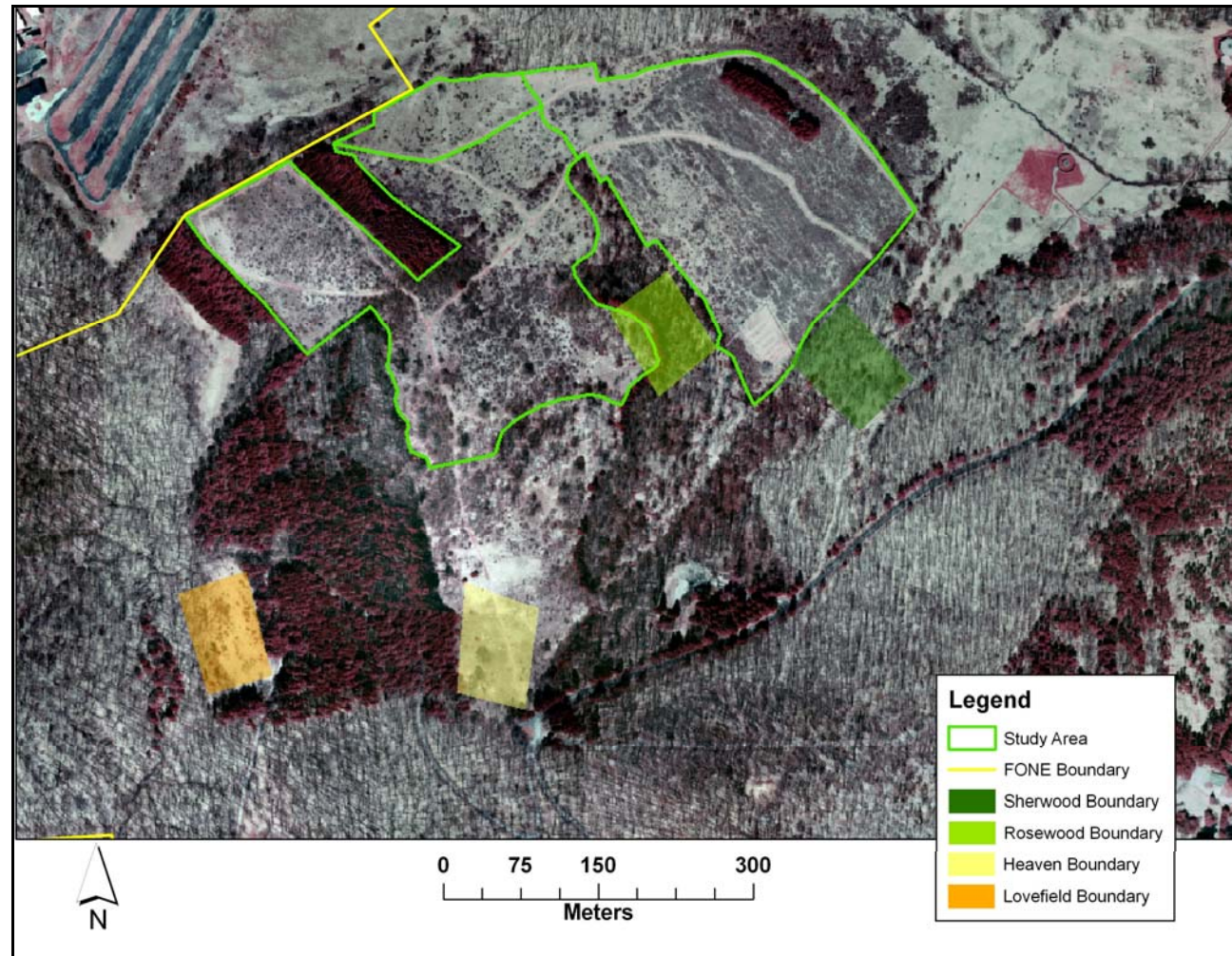


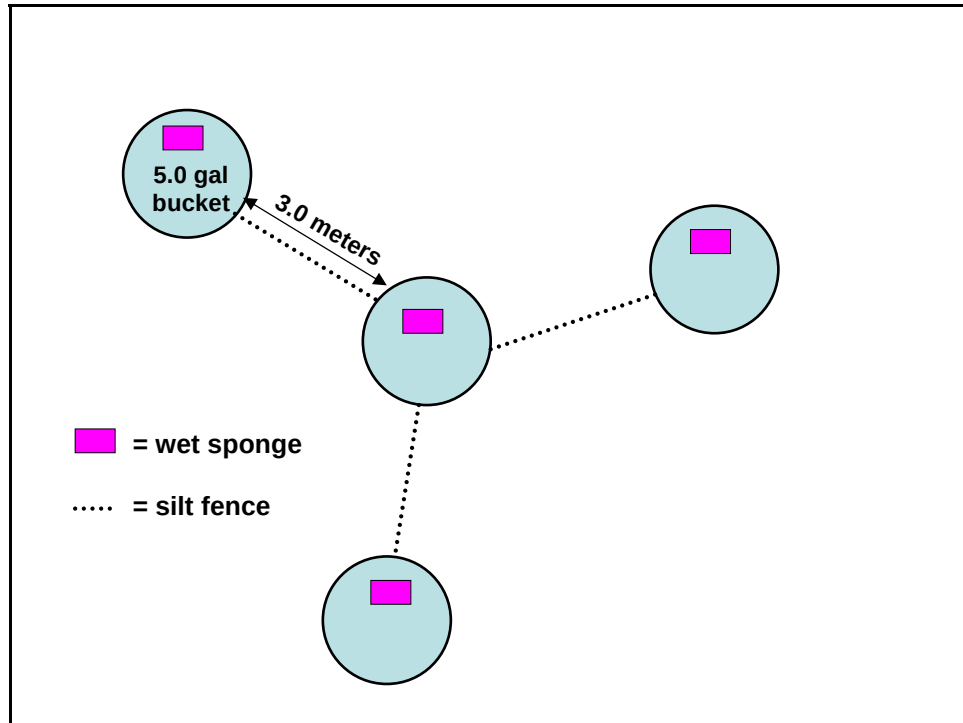
Figure 9. Mean density (earthworms per square meter) and standard error of each earthworm species pooled across all shrub/tree plots and open plots in all months at Fort Necessity National Battlefield from 2004 – 2005.

Appendices

Appendix I. Four of the small mammal grids were located outside the study area; two of the grids (Sherwood and Rosewood) were located in the forest, while the remaining 2 grids (Heaven and Lovefield) were located in old fields.



Appendix II. Each pitfall array consisted of four 20 litter buckets placed in a triad and connected with a 3 m long, 50 cm high silt fence. Six pitfall trap arrays were placed throughout the study area at Fort Necessity National Battlefield.



Appendix III. We calculated mean percent cover and percent frequency of 93 herbaceous species during our pre-treatment surveys in May 2004 and August 2004 within 225 1 × 1-m nested subplots at Fort Necessity National Battlefield, Pennsylvania, U.S.A. Bold-faced species are exotic.

<i>Species</i>	<i>% cover</i>	<i>% frequency</i>
<i>Anthoxanthum odoratum</i>	8.46%	89.8%
<i>Solidago rugosa</i>	3.51%	84.9%
<i>Solidago juncea</i>	2.64%	66.7%
<i>Rubus flagellaris</i>	1.96%	49.3%
<i>Dactylis glomerata</i>	1.88%	56.0%
<i>Symphyotrichum lateriflorum</i>	1.86%	78.2%
<i>Lycopodium digitatum</i>	1.44%	14.7%
<i>Clinopodium vulgare</i>	1.31%	74.2%
<i>Achillea millefolium</i>	1.07%	48.9%
<i>Potentilla simplex</i>	0.96%	62.2%
<i>Holcus lanatus</i>	0.91%	49.8%
<i>Leucanthemum vulgare</i>	0.78%	82.7%
<i>Veronica officinalis</i>	0.77%	52.9%
<i>Hieracium caespitosum</i>	0.76%	66.2%
<i>Prunella vulgaris</i>	0.64%	46.2%
<i>Lonicera morrowii</i>	0.59%	92.0%
<i>Agrostis gigantea</i>	0.51%	8.9%
<i>Danthonia spicata</i>	0.48%	10.7%
<i>Acer rubrum</i>	0.44%	48.0%
<i>Poa trivialis</i>	0.40%	8.4%

Appendix III. Continued.

<i>Species</i>	<i>% cover</i>	<i>% frequency</i>
<i>Plantago lanceolata</i>	0.38%	38.2%
<i>Andropogon virginicus</i>	0.32%	6.2%
<i>Trifolium repens</i>	0.31%	39.1%
<i>Botrychium dissectum</i>	0.31%	47.1%
<i>Ranunculus acris</i>	0.31%	29.3%
<i>Oxalis stricta</i>	0.27%	39.6%
<i>Fragaria virginiana</i>	0.21%	26.7%
<i>Rudbeckia hirta</i>	0.19%	11.6%
<i>Crataegus pruinosa</i>	0.19%	16.9%
<i>Dichanthelium</i> spp.	0.18%	22.7%
<i>Solidago canadensis</i>	0.16%	8.4%
<i>Symphyotrichum puniceum</i>	0.16%	11.1%
<i>Euthamia graminifolia</i>	0.15%	3.6%
<i>Prunus serotina</i>	0.14%	20.4%
<i>Danthonia compressa</i>	0.14%	0.9%
<i>Cerastium fontanum</i>	0.12%	20.9%
<i>Rubus hispidus</i>	0.11%	0.4%
<i>Vernonia gigantea</i> ssp. <i>gigantea</i>	0.10%	4.4%
<i>Daucus carota</i>	0.10%	13.8%
<i>Viburnum recognitum</i>	0.10%	12.4%
<i>Rumex acetosella</i>	0.09%	14.2%
<i>Solidago caesia</i> var. <i>curtisii</i>	0.09%	8.0%
<i>Symphyotrichum prenanthoides</i>	0.08%	9.3%

Appendix III. Continued.

<i>Species</i>	<i>% cover</i>	<i>% frequency</i>
<i>Viola sororia</i>	0.08%	15.1%
<i>Solanum carolinense</i>	0.07%	6.2%
<i>Erigeron strigosus</i> var. <i>strigosus</i>	0.07%	9.3%
<i>Taraxacum officinale</i>	0.06%	7.6%
<i>Malus coronaria</i>	0.05%	2.2%
<i>Trifolium aureum</i>	0.05%	4.0%
<i>Dianthus armeria</i>	0.04%	6.7%
<i>Veronica serpyllifolia</i>	0.04%	7.1%
<i>Stellaria longifolia</i>	0.04%	7.6%
<i>Solidago nemoralis</i>	0.03%	3.1%
<i>Phleum pratense</i>	0.03%	0.9%
<i>Packera aurea</i>	0.02%	0.9%
<i>Symphyotrichum pilosum</i>	0.02%	3.1%
<i>Doellingeria umbellata</i>	0.02%	2.7%
<i>Platanthera lacera</i>	0.02%	3.6%
<i>Clematis virginiana</i>	0.02%	0.9%
<i>Lobelia inflata</i>	0.02%	2.2%
<i>Toxicodendron radicans</i>	0.02%	1.3%
<i>Dichanthelium clandestinum</i>	0.01%	1.8%
<i>Elymus trachycaulus</i>	0.01%	0.4%
<i>Liriodendron tulipifera</i>	0.01%	1.3%
<i>Muhlenbergia schreberi</i>	0.01%	0.9%
<i>Trifolium pratense</i>	0.01%	0.9%

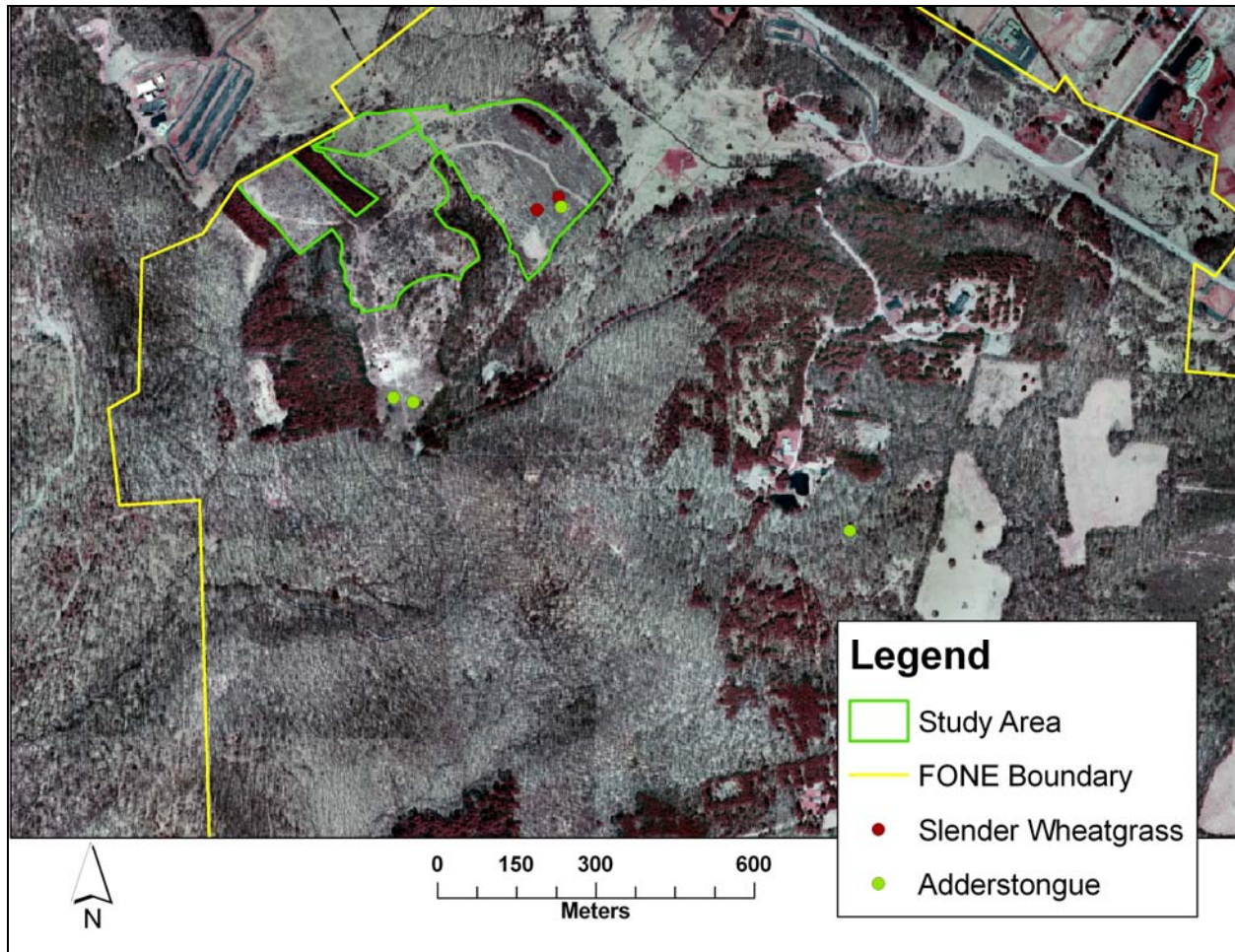
Appendix III. Continued.

<i>Species</i>	<i>% cover</i>	<i>% frequency</i>
<i>Rhus copallinum</i>	0.01%	0.9%
<i>Vitis aestivalis</i>	0.01%	1.3%
<i>Carex blanda</i>	0.01%	0.9%
<i>Hypericum punctatum</i>	0.01%	1.8%
<i>Rosa multiflora</i>	0.01%	1.3%
<i>Fraxinus americana</i>	<0.01%	0.4%
<i>Oenothera perennis</i>	<0.01%	0.9%
<i>Ophioglossum vulgatum</i>	<0.01%	0.4%
<i>Quercus alba</i>	<0.01%	0.9%
<i>Smilax rotundifolia</i>	<0.01%	0.9%
<i>Viola sagittata</i>	<0.01%	0.9%
<i>Allium vineale</i>	<0.01%	0.4%
<i>Ambrosia artemisiifolia</i>	<0.01%	0.4%
<i>Amelanchier arborea</i>	<0.01%	0.4%
<i>Apocynum cannabinum</i>	<0.01%	0.4%
<i>Asplenium platyneuron</i>	<0.01%	0.4%
<i>Berberis thunbergii</i>	<0.01%	0.4%
<i>Botrychium virginianum</i>	<0.01%	0.4%
<i>Juncus tenuis</i>	<0.01%	0.4%
<i>Lactuca canadensis</i>	<0.01%	0.4%
<i>Lysimachia lanceolata</i>	<0.01%	0.4%
<i>Mitchella repens</i>	<0.01%	0.4%
<i>Plantago rugelii</i>	<0.01%	0.4%

Appendix III. Continued.

<i>Species</i>	<i>% cover</i>	<i>% frequency</i>
<i>Quercus rubra</i>	<0.01%	0.4%
<i>Robinia pseudoacacia</i>	<0.01%	0.4%
<i>Sisyrinchium angustifolium</i>	<0.01%	0.4%
<i>Viola blanda</i>	<0.01%	0.4%

Appendix IV. We identified 4 locations of adderstongue (*Ophioglossum vulgatum*) and 1 location of slender wheatgrass (*Elymus trachycaulus*) within the boundaries of Fort Necessity National Battlefield.



Appendix V. Plants and vertebrates listed on the Pennsylvania Natural Heritage Program's species of special concern, which was updated August 2005. Bold-faced species were plants or animals found in the study area at FONE. The list is compiled from our own findings as well as from the following reports: Western Pennsylvania Conservancy 2003, Yahner et al. 2004, and from J. Johnson 2005, bat biologist, personal communication. See following page for rank definitions.

<i>Species</i>	<i>Global Rank</i>	<i>State Rank</i>	<i>State Status</i>	<i>Proposed State Status</i>
<u>Plants</u>				
Slender Wheat Grass <i>Elymus trachycaulus</i>	G5	S3	N	TU
Purple Bluets <i>Houstonia purpurea</i> var. <i>purpurea</i>	G5T5	S1	TU	TU
Bushy St. John's Wort <i>Hypericum densiflorum</i>	G5	S3	PT	PR
<u>Vertebrates - Birds</u>				
Northern Goshawk <i>Accipiter gentilis</i>	G5	S2S3B, S3N	-	CR
Northern Saw-whet Owl <i>Aegolius acadicus</i>	G5	S3B, S3N	-	CU
Great Blue Heron <i>Ardea Herodias</i>	G5	S3S4B, S4N	-	-
Swainson's Thrush <i>Catharus ustulatus</i>	G5	S2S3B, S5N	-	CR
<u>Vertebrates - Mammals</u>				
Northern Myotis <i>Myotis septentrionalis</i>	G4	S3B, S3N	-	CR

Appendix V. Continued.

Rank definitions.

Global Rank:

G5 - Secure - Common, typically widespread and abundant. Typically with considerably more than 100 occurrences and more than 10,000 individuals.

T - Intraspecific Taxon (trinomial) - The status of infraspecific taxa (subspecies or varieties) are indicated by a "T-rank" following the species' global rank. Rules for assigning T ranks follow the same principles outlined above. For example, the global rank of a critically imperiled subspecies of an otherwise widespread and common species would be G5T1. A T subrank cannot imply the subspecies or variety is more abundant than the species= basic rank (e.g., a G1T2 subrank should not occur). A population (e.g., listed under the U.S. Endangered Species Act or assigned candidate status) may be tracked as an infraspecific taxon and given a T rank; in such cases a Q is used after the T rank to denote the taxon's questionable taxonomic status.

State Ranks:

S3 - Vulnerable - Vulnerable in the state either because rare and uncommon, or found only in a restricted range (even if abundant at some locations), or because of other factors making it vulnerable to extirpation. Typically 21 to 100 occurrences.

S2 - Imperiled - Imperiled in the state because of rarity or because of some factor(s) making it very vulnerable to extirpation from the state. Typically 6 to 20 occurrences or few remaining individuals or acres.

S1 - Critically Imperiled - Critically imperiled in the state because of extreme rarity or because of some factor(s) making it especially vulnerable to extirpation from the state. Typically 5 or fewer occurrences or very few remaining individuals or acres.

B - Breeding - Basic rank refers to the breeding population of the Element in the state.

N - Non-breeding - Basic rank refers to the non-breeding population of the Element in the state.

State Status:

N - No current legal status exists, but is under review for future listing.

TU - Tentatively Undetermined - A classification of plant species which are believed to be in danger of population decline, but which cannot presently be included within another classification due to taxonomic uncertainties, limited evidence within historical records, or insufficient data.

PT - Pennsylvania Threatened - Plant species which may become endangered throughout most or all of their natural range within this Commonwealth, if critical habitat is not maintained to prevent their future decline, or if the species is greatly exploited by man.

PX - Pennsylvania Extirpated - Plant species believed by the Department to be extinct within this Commonwealth. These plants may or may not be in existence outside the Commonwealth.

Proposed State Status:

PR - Pennsylvania Rare - Plant species which are uncommon within this Commonwealth. All species of the native wild plants classified as Disjunct, Endemic, Limit of Range and Restricted are included within the Pennsylvania Rare classification.

CR - Candidate Rare - Species which exist only in one of a few restricted geographic areas or habitats within Pennsylvania, or they occur in low numbers over a relatively broad area of the Commonwealth.

CU - Condition Undetermined - Species for which there is insufficient data available to provide an adequate basis for their assignment to other classes or categories.

Appendix VI. List of shrubs and herbs, their exotic/native status, and coefficient of conservatism values (COC) (J. Rentch, West Virginia University, Division of Forestry, unpublished data) from 45 5 x 5-m shrub plots and 225 1 × 1-m nested herb plots placed in a degraded meadow dominated by Morrow's honeysuckle at Fort Necessity National Battlefield during the summer of 2004 and 2005. Bold-faced species are exotic.

<i>Family</i>	<i>Species</i>	<i>Common Name</i>	<i>COC</i>
Aceraceae	<i>Acer rubrum</i> L.	Red Maple	3
Aceraceae	<i>Acer saccharum</i> Marsh. var. <i>saccharum</i>	Sugar Maple	5
Anacardiaceae	<i>Rhus copallinum</i> L.	Winged Sumac	6
Anacardiaceae	<i>Toxicodendron radicans</i> (L.) Kuntze	Eastern Poison Ivy	3
Apiaceae	<i>Daucus carota</i> L.	Queen Anne's Lace	0
Apocynaceae	<i>Apocynum cannabinum</i> L.	Indian Hemp	3
Asclepiadaceae	<i>Asclepias tuberosa</i> L.	Butterfly Milkweed	3
Aspleniaceae	<i>Asplenium platyneuron</i> (L.) B.S.P.	Ebony Spleenwort	5
Asteraceae	<i>Achillea millefolium</i> L. var. <i>occidentalis</i> DC.	Common Yarrow	0
Asteraceae	<i>Ambrosia artemisiifolia</i> L. var. <i>elatior</i> (L.) Descourtils	Annual Ragweed	1
Asteraceae	<i>Cirsium arvense</i> (L.) Scop.	Canada Thistle	0
Asteraceae	<i>Doellingeria umbellata</i> (P. Mill.) Nees var. <i>umbellata</i>	Parasol Whitetop	5
Asteraceae	<i>Erigeron strigosus</i> Muhl. ex Willd. var. <i>strigosus</i>	Prairie Fleabane	2
Asteraceae	<i>Eurybia divaricata</i> (L.) Nesom	White Wood Aster	4
Asteraceae	<i>Euthamia graminifolia</i> (L.) Nutt. var. <i>graminifolia</i>	Flat-top Goldentop	4
Asteraceae	<i>Hieracium caespitosum</i> Dumort.	Meadow Hawkweed	0
Asteraceae	<i>Hypochaeris radicata</i> L.	Hairy Catsear	0
Asteraceae	<i>Lactuca canadensis</i> L.	Canada Lettuce	3
Asteraceae	<i>Leucanthemum vulgare</i> Lam.	Oxeye Daisy	0
Asteraceae	<i>Packera aurea</i> (L.) A. & D. Löve	Golden Ragwort	4
Asteraceae	<i>Rudbeckia hirta</i> L.	Blackeyed Susan	4

Appendix VI. Continued.

<i>Family</i>	<i>Species</i>	<i>Common Name</i>	<i>COC</i>
Asteraceae	<i>Solidago caesia</i> L.	Mountain Decumbent Goldenrod	6
Asteraceae	<i>Solidago canadensis</i> L.	Canada Goldenrod	3
Asteraceae	<i>Solidago juncea</i> Ait.	Early Goldenrod	5
Asteraceae	<i>Solidago nemoralis</i> Ait. var. <i>nemoralis</i>	Gray Goldenrod	5
Asteraceae	<i>Solidago rugosa</i> P. Mill.	Wrinkleleaf Goldenrod	3
Asteraceae	<i>Symphyotrichum lateriflorum</i> (L.) A.& D. Löve	Calico Aster	4
Asteraceae	<i>Symphyotrichum pilosum</i> (Willd.) Nesom	Hairy White Oldfield Aster	4
Asteraceae	<i>Symphyotrichum prenanthoides</i> (Muhl. ex Willd.) Nesom	Crookedstem Aster	5
Asteraceae	<i>Symphyotrichum puniceum</i> (L.) A.& D. Löve var. <i>puniceum</i>	Purplestem Aster	6
Asteraceae	<i>Taraxacum officinale</i> G.H. Weber ex Wiggers ssp. <i>officinale</i>	Common Dandelion	0
Asteraceae	<i>Vernonia gigantea</i> (Walt.) Trel. ssp. <i>gigantea</i>	Giant Ironweed	3
Berberidaceae	<i>Berberis thunbergii</i> DC.	Japanese Barberry	0
Campanulaceae	<i>Lobelia inflata</i> L.	Indian-tobacco	3
Caprifoliaceae	<i>Lonicera morrowii</i> Gray	Morrow's Honeysuckle	0
Caprifoliaceae	<i>Viburnum lentago</i> L.	Nannyberry	7
Caprifoliaceae	<i>Viburnum recognitum</i> Fern.	Southern Arrowwood	6
Caryophyllaceae	<i>Cerastium fontanum</i> Baumg. ssp. <i>vulgare</i> (Hartman) Greuter & Burdet	Common Mouse-ear Chickweed	0
Caryophyllaceae	<i>Dianthus armeria</i> L.	Deptford Pink	0
Caryophyllaceae	<i>Stellaria longifolia</i> Muhl. ex Willd. var. <i>longifolia</i>	Longleaf Starwort	6
Clusiaceae	<i>Hypericum punctatum</i> Lam.	Spotted St. John's Wort	4
Convolvulaceae	<i>Calystegia sepium</i> (L.) R. Br. ssp. <i>sepium</i>	Hedge False Bindweed	0
Cornaceae	<i>Cornus racemosa</i> Lam.	Gray Dogwood	6
Cyperaceae	<i>Carex blanda</i> Dewey	Eastern Woodland Sedge	7
Cyperaceae	<i>Carex debilis</i> Michx. ssp. <i>rudgei</i> (Bailey) A.& D. Löve	White Edge Sedge	6
Cyperaceae	<i>Carex hirsutella</i> Mackenzie	Fuzzy Wuzzy Sedge	4
Cyperaceae	<i>Carex</i> spp.	A sedge	0

Appendix VI. Continued.

<i>Family</i>	<i>Species</i>	<i>Common Name</i>	<i>COC</i>
Elaeagnaceae	<i>Elaeagnus umbellata</i> Thunb. var. <i>parvifolia</i> (Royle) Schneid.	Autumn Olive	0
Ericaceae	<i>Vaccinium stamineum</i> L.	Deerberry	4
Fabaceae	<i>Robinia pseudoacacia</i> L.	Black Locust	2
Fabaceae	<i>Trifolium aureum</i> Pollich	Golden Clover	0
Fabaceae	<i>Trifolium pratense</i> L.	Red Clover	0
Fabaceae	<i>Trifolium repens</i> L.	White Clover	0
Fagaceae	<i>Quercus alba</i> L.	White Oak	5
Fagaceae	<i>Quercus rubra</i> L.	Northern Red Oak	5
Iridaceae	<i>Sisyrinchium angustifolium</i> P. Mill.	Narrowleaf Blue-eyed Grass	4
Juncaceae	<i>Juncus tenuis</i> Willd.	Poverty Rush	3
Lamiaceae	<i>Clinopodium vulgare</i> L.	Wild Basil	2
Lamiaceae	<i>Lycopus virginicus</i> L.	Virginia Water Horehound	4
Lamiaceae	<i>Prunella vulgaris</i> L.	Common Selfheal	1
Lauraceae	<i>Sassafras albidum</i> (Nutt.) Nees	Sassafras	4
Lilliaceae	<i>Allium vineale</i> L. ssp. <i>Vineale</i>	Wild Garlic	0
Lycopodiaceae	<i>Lycopodium clavatum</i> L.	Running Clubmoss	5
Lycopodiaceae	<i>Lycopodium digitatum</i> Dill. ex A. Braun	Fan Clubmoss	4
Magnoliaceae	<i>Liriodendron tulipifera</i> L.	Tulip Poplar	5
Nyssaceae	<i>Nyssa sylvatica</i> Marsh.	Black Gum	4
Oleaceae	<i>Fraxinus americana</i> L.	White Ash	6
Onagraceae	<i>Oenothera perennis</i> L.	Little Evening Primrose	5
Ophioglossaceae	<i>Botrychium dissectum</i> Spreng.	Cutleaf Grapefern	4
Ophioglossaceae	<i>Botrychium virginianum</i> (L.) Sw.	Rattlesnake Fern	5
Ophioglossaceae	<i>Ophioglossum vulgatum</i> L.	Adderstongue	7
Orchidaceae	<i>Platanthera lacera</i> (Michx.) G. Don	Green Fringed Orchid	6
Oxalidaceae	<i>Oxalis stricta</i> L.	Common Yellow Oxalis	2

Appendix VI. Continued.

<i>Family</i>	<i>Species</i>	<i>Common Name</i>	<i>COC</i>
Plantaginaceae	<i>Plantago lanceolata</i> L.	Narrowleaf Plantain	0
Plantaginaceae	<i>Plantago rugelii</i> Dcne. var. <i>rugelii</i>	Blackseed Plantain	2
Poaceae	<i>Agrostis gigantea</i> Roth	Redtop	0
Poaceae	<i>Andropogon virginicus</i> L. var. <i>virginicus</i>	Broomsedge Bluestem	3
Poaceae	<i>Anthoxanthum odoratum</i> L. ssp. <i>odoratum</i>	Sweet Vernal Grass	0
Poaceae	<i>Arrhenatherum elatius</i> (L.) Beauv. Ex J.& K. Presl	Tall Oatgrass	0
Poaceae	<i>Bromus inermis</i> Leyss. ssp. <i>inermis</i> var. <i>inermis</i>	Smooth Brome	0
Poaceae	<i>Dactylis glomerata</i> L. ssp. <i>glomerata</i>	Orchard Grass	0
Poaceae	<i>Danthonia compressa</i> Austin ex Peck	Flattened Oatgrass	6
Poaceae	<i>Danthonia spicata</i> (L.) Beauv. ex Roemer & J.A. Schultes	Poverty Oatgrass	5
Poaceae	<i>Dichanthelium clandestinum</i> (L.) Gould	Deertongue	3
Poaceae	<i>Dichanthelium meridionale</i> (Ashe) Freckman	Matting Rosette Grass	6
Poaceae	<i>Dichanthelium sphaerocarpon</i> (Ell.) Gould	Roundseed Panicgrass	4
Poaceae	<i>Dichanthelium</i> spp.	Panic Grass	0
Poaceae	<i>Elymus repens</i> (L.) Gould	Quackgrass	0
Poaceae	<i>Elymus trachycaulus</i> (Link) Gould ex Shinnars ssp. <i>trachycaulus</i>	Slender Wheatgrass	8
Poaceae	<i>Glyceria striata</i> (Lam.) A.S. Hitchc.	Fowl Mannagrass	5
Poaceae	<i>Holcus lanatus</i> L.	Common Velvet Grass	0
Poaceae	<i>Muhlenbergia schreberi</i> J.F. Gmel.	Nimblewill	5
Poaceae	<i>Muhlenbergia</i> spp.	Muhly	0
Poaceae	<i>Phleum pratense</i> L.	Timothy	0
Poaceae	<i>Poa palustris</i> L.	Fowl Bluegrass	6
Poaceae	<i>Poa trivialis</i> L.	Rough Bluegrass	0
Poaceae	<i>Tridens flavus</i> (L.) A.S. Hitchc. var. <i>flavus</i>	Purpletop Tridens	3
Polygalaceae	<i>Polygala verticillata</i> L.	Whorled Milkwort	6
Polygonaceae	<i>Polygonum persicaria</i> L.	Spotted Ladysthumb	0

Appendix VI. Continued.

<i>Family</i>	<i>Species</i>	<i>Common Name</i>	<i>COC</i>
Polygonaceae	<i>Rumex acetosella</i> L.	Sheep Sorrel	0
Primulaceae	<i>Lysimachia lanceolata</i> Walt.	Lanceleaf Loosestrife	6
Ranunculaceae	<i>Clematis virginiana</i> L.	Virgin's Bower	4
Ranunculaceae	<i>Ranunculus acris</i> L. var. <i>acris</i>	Tall Buttercup	0
Rosaceae	<i>Agrimonia gryposepala</i> Wallr.	Tall Hairy Agrimony	4
Rosaceae	<i>Amelanchier arborea</i> (Michx. f.) Fern. var. <i>arborea</i>	Common Serviceberry	5
Rosaceae	<i>Crataegus pruinosa</i> (Wendl. f.) K. Koch	Waxyfruit Hawthorne	5
Rosaceae	<i>Fragaria virginiana</i> Duchesne ssp. <i>virginiana</i>	Virginia Strawberry	3
Rosaceae	<i>Malus coronaria</i> (L.) P. Mill. var. <i>coronaria</i>	Sweet Crabapple	3
Rosaceae	<i>Potentilla simplex</i> Michx.	Common Cinquefoil	4
Rosaceae	<i>Prunus mahaleb</i> L.	Mahaleb Cherry	0
Rosaceae	<i>Prunus serotina</i> Ehrh. var. <i>serotina</i>	Black Cherry	4
Rosaceae	<i>Rosa multiflora</i> Thunb. ex Murr.	Multiflora Rose	0
Rosaceae	<i>Rubus flagellaris</i> Willd.	Northern Dewberry	5
Rosaceae	<i>Rubus hispidus</i> L.	Bristly Dewberry	5
Rubiaceae	<i>Mitchella repens</i> L.	Partridgeberry	5
Scrophulariaceae	<i>Veronica officinalis</i> L.	Common Gypsyweed	0
Scrophulariaceae	<i>Veronica serpyllifolia</i> L. ssp. <i>serpyllifolia</i>	Thymeleaf Speedwell	0
Simaroubaceae	<i>Ailanthus altissima</i> (P. Mill.) Swingle	Tree of Heaven	0
Smilacaceae	<i>Smilax glauca</i> Walt.	Cat Greenbrier	5
Smilacaceae	<i>Smilax rotundifolia</i> L.	Roundleaf Greenbrier	4
Solanaceae	<i>Physalis heterophylla</i> Nees var. <i>heterophylla</i>	Clammy Groundcherry	3
Solanaceae	<i>Solanum carolinense</i> L. var. <i>carolinense</i>	Carolina Horsenettle	3
Violaceae	<i>Viola blanda</i> Willd.	Sweet White Violet	5
Violaceae	<i>Viola sagittata</i> Ait.	Arrowleaf Violet	6
Violaceae	<i>Viola sororia</i> Willd.	Common Blue Violet	4

Appendix VI. Continued.

<i>Family</i>	<i>Species</i>	<i>Common Name</i>	<i>COC</i>
Vitaceae	<i>Vitis aestivalis</i> Michx.	Summer Grape	5

Appendix VII. List of all 243 flora recorded during 2004 and 2005 at Fort Necessity National Battlefield, Pennsylvania. List includes species recorded from Morrow's honeysuckle removal study, invertebrate study, small mammal microhabitat study, and casual observations. Voucher specimens indicated with an asterisk (*). Bold-faced species are exotic.

<i>Family</i>	<i>Species</i>	<i>Common Name</i>
Aceraceae	<i>Acer rubrum</i>	Red Maple
Aceraceae	<i>Acer saccharum</i>	Sugar Maple
Anacardiaceae	<i>Rhus copallinum</i>	Winged Sumac
Anacardiaceae	<i>Toxicodendron radicans</i>	Eastern Poison Ivy
Apiaceae	<i>Daucus carota</i>	Queen Anne's Lace
Apiaceae	<i>Osmorhiza claytonii</i>	Clayton's Sweetroot
Apiaceae	* <i>Sanicula canadensis</i>	Canadian Black Snakeroot
Apiaceae	* <i>Zizia aptera</i>	Meadow Zizia
Apocynaceae	<i>Apocynum cannabinum</i>	Indian Hemp
Araceae	<i>Symplocarpus foetidus</i>	Skunk Cabbage
Asclepiadaceae	<i>Asclepias syriaca</i>	Common Milkweed
Asclepiadaceae	* <i>Asclepias tuberosa</i>	Butterfly Milkweed
Aspleniaceae	<i>Asplenium platyneuron</i>	Ebony Spleenwort
Asteraceae	*<i>Achillea millefolium</i>	Common Yarrow
Asteraceae	* <i>Ageratina altissima</i> var. <i>altissima</i>	White Snakeroot
Asteraceae	<i>Ambrosia artemisiifolia</i>	Annual Ragweed
Asteraceae	<i>Antennaria neglecta</i>	Field Pussytoes
Asteraceae	*<i>Cirsium arvense</i>	Canada Thistle
Asteraceae	* <i>Doellingeria umbellata</i>	Parasol Whitetop
Asteraceae	* <i>Erigeron strigosus</i> var. <i>strigosus</i>	Prairie Fleabane
Asteraceae	* <i>Eurybia divaricata</i>	White Wood Aster
Asteraceae	* <i>Euthamia graminifolia</i>	Flat-top Goldentop
Asteraceae	*<i>Hieracium aurantiacum</i>	Orange Hawkweed
Asteraceae	*<i>Hieracium caespitosum</i>	Meadow Hawkweed
Asteraceae	*<i>Hypochaeris radicata</i>	Hairy Catsear
Asteraceae	* <i>Lactuca canadensis</i>	Canada Lettuce
Asteraceae	*<i>Leucanthemum vulgare</i>	Oxeye Daisy
Asteraceae	<i>Packera aurea</i>	Golden Ragwort
Asteraceae	* <i>Prenanthes</i> spp.	Rattlesnakeroot
Asteraceae	* <i>Rudbeckia hirta</i>	Blackeyed Susan
Asteraceae	* <i>Solidago caesia</i>	Mountain Decumbent Goldenrod
Asteraceae	* <i>Solidago canadensis</i>	Canada Goldenrod
Asteraceae	* <i>Solidago juncea</i>	Early Goldenrod
Asteraceae	* <i>Solidago nemoralis</i>	Gray Goldenrod
Asteraceae	<i>Solidago rugosa</i>	Wrinkleleaf Goldenrod
Asteraceae	* <i>Symphyotrichum lateriflorum</i>	Calico Aster
Asteraceae	<i>Symphyotrichum pilosum</i>	Hairy White Oldfield Aster
Asteraceae	* <i>Symphyotrichum prenanthoides</i>	Crookedstem Aster
Asteraceae	* <i>Symphyotrichum puniceum</i>	Purplestem Aster
Asteraceae	<i>Taraxacum officinale</i>	Common Dandelion
Asteraceae	* <i>Vernonia gigantea</i> ssp. <i>gigantea</i>	Giant Ironweed

Appendix VII. Continued.

<i>Family</i>	<i>Species</i>	<i>Common Name</i>
Balsalminaceae	<i>Impatiens capensis</i>	Jewelweed
Berberidaceae	<i>Berberis thunbergii</i>	Japanese Barberry
Berberidaceae	<i>Podophyllum peltatum</i>	Mayapple
Betulaceae	<i>Betula alleghaniensis</i>	Yellow Birch
Betulaceae	<i>Carpinus caroliniana</i>	Iron Wood
Brassicaceae	*<i>Barbarea vulgaris</i>	Garden Yellowrocket
Brassicaceae	<i>Cardamine diphylla</i>	Crinkleroot
Brassicaceae	<i>Cardamine hirsuta</i>	Hairy Bittercress
Campanulaceae	* <i>Lobelia inflata</i>	Indian-tobacco
Caprifoliaceae	*<i>Lonicera morrowii</i>	Morrow's Honeysuckle
Caprifoliaceae	* <i>Sambucus nigra</i> spp. <i>canadensis</i>	Common Elderberry
Caprifoliaceae	* <i>Viburnum lentago</i>	Nannyberry
Caprifoliaceae	* <i>Viburnum recognitum</i>	Southern Arrowwood
Caryophyllaceae	<i>Cerastium fontanum</i>	Common Mouse-ear Chickweed
Caryophyllaceae	*<i>Dianthus armeria</i>	Deptford Pink
Caryophyllaceae	* <i>Stellaria longifolia</i>	Longleaf Starwort
Celastraceae	<i>Euonymus alata</i>	Winged Burning Bush
Clusiaceae	* <i>Hypericum punctatum</i>	Spotted St. John's Wort
Convolvulaceae	*<i>Calystegia sepium</i>	Hedge False Bindweed
Convolvulaceae	*<i>Convolvulus arvensis</i>	Field Bindweed
Convolvulaceae	* <i>Ipomea pandurata</i>	Man of the Earth
Cornaceae	<i>Cornus florida</i>	Flowering Dogwood
Cornaceae	<i>Cornus racemosa</i>	Gray Dogwood
Cornaceae	<i>Cornus sericea</i>	Redosier Dogwood
Cyperaceae	* <i>Carex blanda</i>	Eastern Woodland Sedge
Cyperaceae	* <i>Carex debilis</i> var. <i>rudgei</i>	White Edge Sedge
Cyperaceae	* <i>Carex digitalis</i>	Slender Woodland Sedge
Cyperaceae	* <i>Carex granularis</i>	Limestone Meadow Sedge
Cyperaceae	* <i>Carex hirsutella</i>	Fuzzy Wuzzy Sedge
Cyperaceae	* <i>Carex laxiflora</i>	Broad Looseflower Sedge
Cyperaceae	* <i>Carex lurida</i>	Shallow Sedge
Cyperaceae	* <i>Carex molesta</i>	Troublesome Sedge
Cyperaceae	* <i>Carex normalis</i>	Greater Straw Sedge
Cyperaceae	* <i>Carex radiata</i>	Eastern Star Sedge
Cyperaceae	* <i>Carex</i> spp.	Carex spp.
Cyperaceae	* <i>Carex stipata</i>	Owlfruit Sedge
Cyperaceae	* <i>Carex swanii</i>	Swan's Sedge
Cyperaceae	* <i>Carex virescens</i>	Ribbed Sedge
Cyperaceae	* <i>Carex vulpinoidea</i>	Fox Sedge
Cyperaceae	<i>Eleocharis tenuis</i>	Slender Spikerush
Cyperaceae	<i>Schoenoplectus purshianus</i>	Weakstalk Bulrush
Cyperaceae	* <i>Scirpus polyphyllus</i>	Leafy Bulrush
Dennstaedtiaceae	* <i>Dennstaedtia punctilobula</i>	Eastern Hayscented Fern
Dennstaedtiaceae	* <i>Pteridium aquilinum</i>	Western Brackenfern
Dioscoreaceae	<i>Dioscorea villosa</i>	Wild Yam
Dryopteridaceae	<i>Athyrium filix-femina</i> ssp. <i>angustum</i>	Subarctic Ladyfern
Dryopteridaceae	* <i>Dryopteris carthusiana</i>	Spinulose Woodfern

Appendix VII. Continued.

<i>Family</i>	<i>Species</i>	<i>Common Name</i>
Dryopteridaceae	<i>Dryopteris intermedia</i>	Intermediate Woodfern
Dryopteridaceae	<i>Onoclea sensibilis</i>	Sensitive Fern
Dryopteridaceae	* <i>Polystichum acrostichoides</i>	Christmas Fern
Elaeagnaceae	<i>Elaeagnus umbellata</i>	Autumn Olive
Ericaceae	<i>Rhododendron periclymenoides</i>	Pink Azalea
Ericaceae	<i>Vaccinium pallidum</i>	Blue Ridge Blueberry
Ericaceae	* <i>Vaccinium stamineum</i>	Deerberry
Fabaceae	<i>Amphicarpaea bracteata</i>	American Hogpeanut
Fabaceae	*<i>Coronilla varia</i>	Crown Vetch
Fabaceae	<i>Desmodium canescens</i>	Hoary Ticktrefoil
Fabaceae	* <i>Desmodium paniculatum</i>	Panicledleaf Ticktrefoil
Fabaceae	<i>Robinia pseudoacacia</i>	Black Locust
Fabaceae	*<i>Trifolium aureum</i>	Golden Clover
Fabaceae	<i>Trifolium pratense</i>	Red Clover
Fabaceae	<i>Trifolium repens</i>	White Clover
Fagaceae	<i>Fagus grandifolia</i>	American Beech
Fagaceae	<i>Quercus alba</i>	White Oak
Fagaceae	<i>Quercus coccinea</i>	Scarlet Oak
Fagaceae	<i>Quercus rubra</i>	Northern Red Oak
Fagaceae	<i>Quercus velutina</i>	Black Oak
Gentianaceae	<i>Gentian clausa</i>	Bottle Gentian
Geraniaceae	<i>Geranium maculatum</i>	Spotted Geranium
Iridaceae	<i>Sisyrinchium angustifolium</i>	Narrowleaf Blue-eyed Grass
Juglandaceae	<i>Carya glabra</i>	Pignut Hickory
Juglandaceae	<i>Carya tomentosa</i>	Mockernut Hickory
Juncaceae	<i>Juncus effusus</i>	Common Rush
Juncaceae	* <i>Juncus secundus</i>	Lopsided Rush
Juncaceae	* <i>Juncus tenuis</i>	Poverty Rush
Juncaceae	* <i>Luzula acuminata</i>	Hairy Woodrush
Lamiaceae	* <i>Clinopodium vulgare</i>	Wild Basil
Lamiaceae	*<i>Glechoma hederaceae</i>	Ground Ivy
Lamiaceae	* <i>Lycopus uniflorus</i>	Northern Bugleweed
Lamiaceae	* <i>Lycopus virginicus</i>	Virginia Water Horehound
Lamiaceae	* <i>Prunella vulgaris</i>	Common Selfheal
Lamiaceae	* <i>Scutellaria incana</i>	Hoary Skullcap
Lamiaceae	<i>Teucrium canadense</i>	Canada Germander
Lauraceae	<i>Lindera benzoin</i>	Spicebush
Lauraceae	<i>Sassafras albidum</i>	Sassafras
Lilliaceae	<i>Allium vineale</i>	Wild Garlic
Lilliaceae	<i>Lilium superbum</i>	Turk's-cap Lilly
Lilliaceae	* <i>Polygonatum biflorum</i>	Smooth Solomon's Seal
Lilliaceae	* <i>Uvularia perfoliata</i>	Perfoliate Bellwort
Lilliaceae	* <i>Uvularia sessilifolia</i>	Sessileleaf Bellwort
Linaceae	* <i>Linum striatum</i>	Ridged Yellow Flax
Lycopodiaceae	* <i>Lycopodium clavatum</i>	Running Clubmoss
Lycopodiaceae	<i>Lycopodium digitatum</i>	Fan Clubmoss
Magnoliaceae	<i>Liriodendron tulipifera</i>	Tulip Poplar

Appendix VII. Continued.

<i>Family</i>	<i>Species</i>	<i>Common Name</i>
Magnoliaceae	<i>Magnolia acuminata</i>	Cucumber Tree
Monotropaceae	<i>Monotropa uniflora</i>	Indian Pipe
Nyssaceae	<i>Nyssa sylvatica</i>	Black Gum
Oleaceae	<i>Fraxinus americana</i>	White Ash
Onagraceae	* <i>Circaea lutetiana</i>	Broadleaf Enchanter's Nightshade
Onagraceae	* <i>Oenothera perennis</i>	Little Evening Primrose
Ophioglossaceae	<i>Botrychium dissectum</i>	Cutleaf Grapefern
Ophioglossaceae	* <i>Botrychium virginianum</i>	Rattlesnake Fern
Ophioglossaceae	** <i>Ophioglossum vulgatum</i>	Adderstongue
Orchidaceae	<i>Liparis lilifolia</i>	Brown Widelif Orchid
Orchidaceae	<i>Platanthera lacera</i>	Green Fringed Orchid
Osmundaceae	<i>Osmunda cinnamomea</i>	Cinnamon Fern
Oxalidaceae	* <i>Oxalis stricta</i>	Common Yellow Oxalis
Pinaceae	<i>Picea rubens</i>	Red Spruce
Pinaceae	<i>Pinus resinosa</i>	Red Pine
Pinaceae	<i>Pinus strobus</i>	White Pine
Plantaginaceae	<i>Plantago lanceolata</i>	Narrowleaf Plantain
Plantaginaceae	* <i>Plantago rugelii</i>	Blackseed Plantain
Poaceae	*<i>Agrostis gigantea</i>	Redtop
Poaceae	* <i>Agrostis perennans</i>	Upland Bentgrass
Poaceae	<i>Andropogon virginicus</i>	Broomsedge Bluestem
Poaceae	*<i>Anthoxanthum odoratum</i>	Sweet Vernal Grass
Poaceae	*<i>Arrhenatherum elatius</i>	Tall Oatgrass
Poaceae	* <i>Brachyelytrum erectum</i>	Bearded Shorthusk
Poaceae	*<i>Bromus inermis</i>	Smooth Brome
Poaceae	* <i>Cinna arundinaceae</i>	Sweet Woodreed
Poaceae	*<i>Dactylis glomerata</i>	Orchard Grass
Poaceae	* <i>Danthonia compressa</i>	Flattened Oatgrass
Poaceae	* <i>Danthonia spicata</i>	Poverty Oatgrass
Poaceae	* <i>Dichanthelium acuminatum</i> var. <i>fasciculatum</i>	Western Panicgrass
Poaceae	* <i>Dichanthelium clandestinum</i>	Deertongue
Poaceae	* <i>Dichanthelium meridionale</i>	Matting Rosette Grass
Poaceae	* <i>Dichanthelium scabriusculum</i>	Wooly Rosette Grass
Poaceae	* <i>Dichanthelium sphaerocarpon</i>	Roundseed Panicgrass
Poaceae	<i>Dichanthelium</i> spp.	Panic Grass
Poaceae	* <i>Elymus canadensis</i>	Canada Wildrye
Poaceae	*<i>Elymus repens</i>	Quackgrass
Poaceae	* <i>Elymus trachycaulus</i>	Slender Wheatgrass
Poaceae	* <i>Festuca trachyphylla</i>	Hard Fescue
Poaceae	* <i>Glyceria striata</i>	Fowl Mannagrass
Poaceae	*<i>Holcus lanatus</i>	Common Velvet Grass
Poaceae	* <i>Leersia oryzoides</i>	Rice Cutgrass
Poaceae	* <i>Leersia virginica</i>	Whitegrass
Poaceae	*<i>Lolium arundinaceum</i>	Tall Fescue
Poaceae	<i>Microstegium vimineum</i>	Japanese Stiltgrass
Poaceae	* <i>Muhlenbergia schreberi</i>	Nimblewill
Poaceae	* <i>Muhlenbergia</i> spp.	Muhly

Appendix VII. Continued.

<i>Family</i>	<i>Species</i>	<i>Common Name</i>
Poaceae	*Phleum pratense	Timothy
Poaceae	*Poa alsodes	Grove Bluegrass
Poaceae	*Poa palustris	Fowl Bluegrass
Poaceae	*Poa trivialis	Rough Bluegrass
Poaceae	*Tridens flavus	Purpletop Tridens
Polygalaceae	*Polygala sanguinea	Purple Milkwort
Polygalaceae	*Polygala verticillata	Whorled Milkwort
Polygonaceae	*Polygonum persicaria	Spotted Ladysthumb
Polygonaceae	*Polygonum sagittatum	Arrowleaf Tearthumb
Polygonaceae	*Polygonum virginianum	Jumpseed
Polygonaceae	*Rumex acetosella	Sheep Sorrel
Polygonaceae	Rumex crispus	Curly Dock
Primulaceae	*Lysimachia lanceolata	Lanceleaf Loosestrife
Primulaceae	Lysimachia quadrifolia	Whorled Yellow Loosestrife
Ranunculaceae	Clematis virginiana	Virgin's Bower
Ranunculaceae	*Ranunculus acris	Tall Buttercup
Ranunculaceae	Thalictrum dioicum	Early Meadow-rue
Rosaceae	*Agrimonia gryposepala	Tall Hairy Agrimony
Rosaceae	Amelanchier arborea	Common Serviceberry
Rosaceae	*Crataegus pruinosa	Waxyfruit Hawthorne
Rosaceae	Crataegus spp.	Hawthorne
Rosaceae	Fragaria virginiana	Virginia Strawberry
Rosaceae	Geum canadense	White Avens
Rosaceae	*Malus coronaria	Sweet Crabapple
Rosaceae	*Malus floribunda	Japanese Flowering Crabapple
Rosaceae	*Malus pumila	Paradise Apple
Rosaceae	Physocarpus opulifolius	Common Ninebark
Rosaceae	Potentilla simplex	Common Cinquefoil
Rosaceae	Prunus mahaleb	Mahaleb Cherry
Rosaceae	Prunus serotina	Black Cherry
Rosaceae	Rosa multiflora	Multiflora Rose
Rosaceae	*Rubus flagellaris	Northern Dewberry
Rosaceae	*Rubus hispidus	Bristly Dewberry
Rubiaceae	*Gallium circaezans	Licorice Bedstraw
Rubiaceae	*Gallium triflorum	Fragrant Bedstraw
Rubiaceae	*Houstonia purpurea var. purpurea	Purple Bluets
Rubiaceae	*Mitchella repens	Partridgeberry
Salicaceae	Populus deltoides	Eastern Cottonwood
Salicaceae	*Populus grandidentata	Bigtooth Aspen
Saxifragaceae	Mitella diphylla	Twoleaf Miterwort
Scrophulariaceae	*Mimulus ringens	Allegheny Monkeyflower
Scrophulariaceae	*Penstemon digitalis	Talus Slope Penstemon
Scrophulariaceae	Veronica arvensis	Corn Speedwell
Scrophulariaceae	Veronica officinalis	Common Gypsyweed
Scrophulariaceae	*Veronica serpyllifolia	Thymeleaf Speedwell
Scrophulariaceae	*Veronicastrum virginicum	Culver's Root
Simaroubaceae	Ailanthus altissima	Tree of Heaven

Appendix VII. Continued.

<i>Family</i>	<i>Species</i>	<i>Common Name</i>
Smilacaceae	<i>Smilax glauca</i>	Cat Greenbrier
Smilacaceae	<i>Smilax rotundifolia</i>	Roundleaf Greenbrier
Smilacaceae	* <i>Smilax tamnoides</i>	Bristly Greenbrier
Solanaceae	* <i>Physalis heterophylla</i>	Clammy Groundcherry
Solanaceae	<i>Solanum carolinense</i>	Carolina Horsenettle
Thelypteridaceae	* <i>Thelypteris noveboracensis</i>	New York Fern
Verbenaceae	* <i>Verbena urticifolia</i>	White Vervain
Violaceae	<i>Viola blanda</i>	Sweet White Violet
Violaceae	* <i>Viola conspersa</i>	American Dog Violet
Violaceae	<i>Viola rotundifolia</i>	Roundleaf Yellow Violet
Violaceae	<i>Viola sagittata</i>	Arrowleaf Violet
Violaceae	* <i>Viola sororia</i>	Common Blue Violet
Vitaceae	<i>Parthenocissus quinquefolia</i>	Virginia Creeper
Vitaceae	<i>Vitis aestivalis</i>	Summer Grape

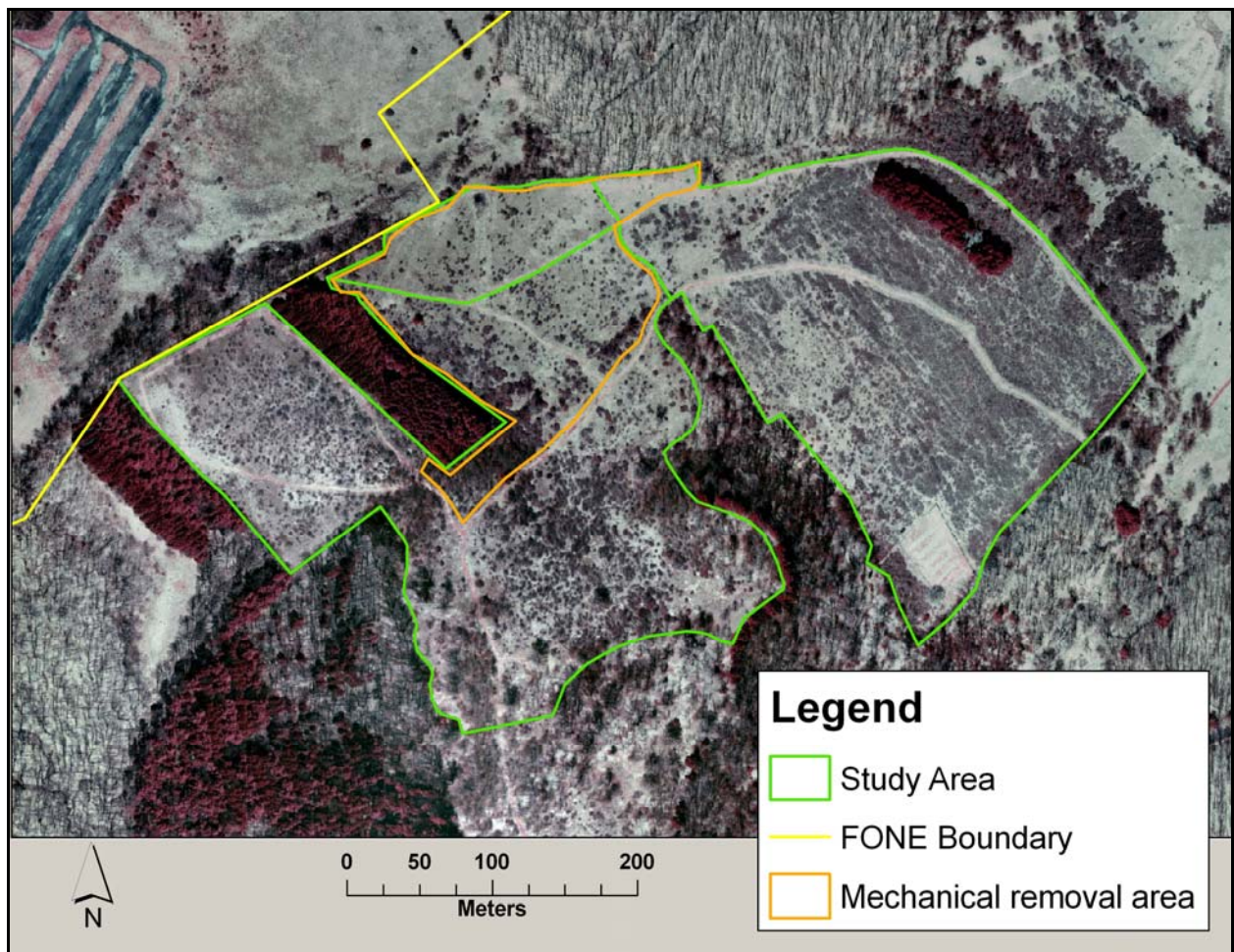
Appendix VIII. We recorded 8 new park species at Fort Necessity National Battlefield during the summer of 2004 and 2005, including 6 mammals, 1 reptile, and 1 amphibian.

<u>Species</u>	<u>Comments</u>
<u>Mammals</u>	
Starnose mole (<i>Condylura cristata</i>)	Zoo pitfall
Hairytail mole (<i>Parascalops breweri</i>)	Dead on Braddock Trace near study area
Smoky shrew (<i>Sorex fumeus</i>)	Zoo and Nursery pitfall
Meadow jumping mouse (<i>Zapus hudsonius</i>)	Throughout study area
Southern bog lemming (<i>Synaptomys cooperi</i>)	Zoo small mammal grid
Southern flying squirrel (<i>Glaucomys volans</i>)	Sherwood small mammal grid
<u>Reptiles</u>	
Northern ring-necked snake (<i>Diadophis punctatatus edwardsii</i>)	Upland pitfall trap; outside GMC
<u>Amphibians</u>	
Long-tailed salamander (<i>Eurycea longicauda</i>)	Under wood pile at GMC

Appendix IX. The overabundant deer population has decreased herb diversity and led to an understory dominated by ferns and black cherry in much of the forest at Fort Necessity National Battlefield.



Appendix X. Approximately 2.75 ha of thinly scattered Morrow's honeysuckle should be treated by mechanically removing the shrubs. The study area outside the mechanical removal area should be treated with a foliar application of glyphosate in October, followed by bush-hogging in May.



Appendix XI. Suggested seed list of native herbs and grasses. This list was developed with the help of W. Grafton. Plants from list are found in the Ernst Native Seed & Plant Material brochure (edition 34).

<i>Species</i>	<i>Common name</i>	<i>Ecotype</i>	<i>% of mix</i>
<u>Grasses</u>			
<i>Andropogon gerardii</i>	Big bluestem	Niagara – NY	10%
<i>Elymus canadensis</i>	Canada wild rye	PA	10%
<i>Schizachyrium scoparium</i>	Little bluestem	PA	10%
<i>Tridens flavus</i>	Purple top	MD & PA	10%
<u>Herbs</u>			
<i>Apocynum cannabinum</i>	Indian hemp	PA	2%
<i>Asclepias syriaca</i>	Common milkweed	PA	10%
<i>Asclepias tuberosa</i>	Butterfly milkweed	PA	2%
<i>Aster firmus</i>	Shining aster	PA	2%
<i>Aster novae-angliae</i>	New England aster	PA	3%
<i>Aster puniceus</i>	Purple stemmed aster	PA	2%
<i>Aster umbellatus</i>	Flat topped white aster	PA	2%
<i>Aster pilosus</i>	Heath aster	PA	1%
<i>Desmodium canadense</i>	Showy tick trefoil	PA	3%
<i>Eupatorium fistulosum</i>	Joe pye weed	PA	3%
<i>Eupatorium maculatum</i>	Spotted joe pye weed	PA	2%
<i>Eupatorium rugosum</i>	White snakeroot	PA	1%
<i>Heliathus giganteus</i>	Giant sunflower	PA	1%
<i>Helopsis helianthoides</i>	Ox eye sunflower	PA	2%
<i>Liatris spicata</i>	Blazing star	PA	2%
<i>Penstemon digitalis</i>	Tall white beard tongue	WV	1%
<i>Penstemon laevigatus</i>	Appalachian beard tongue	PA	1%
<i>Phytolacca americana</i>	Pokeweed	PA	3%
<i>Pycnanthemum muticum</i>	Bigleaf mountain mint	PA	2%
<i>Sencio aureus</i>	Golden ragwort	PA	2%
<i>Senna marilandica</i>	Maryland senna	PA	4%
<i>Vernonia noveboracensis</i>	New York ironweed	WV	2%
<i>Vernonia gigantea</i>	Giant ironweed	PA	2%
<i>Verbena urticifolia</i>	White vervain	PA	1%
<u>Woody species</u>			
<i>Cornus racemosa</i>	Grey dogwood	PA	3%
<i>Physocarpus opulifolius</i>	Common ninebark	PA	1%

Appendix XII. The nursery at FONE has 6 species of tree saplings, as well as 4 “volunteer” species of shrubs and trees, for a total of 308 saplings that can be planted as of July 2005.

<i>Species</i>	<i>Number</i>
Northern Red Oak (<i>Quercus rubra</i>)	82
Chestnut Oak (<i>Quercus prinus</i>)	74
White Oak (<i>Quercus alba</i>)	47
Sugar Maple (<i>Acer saccharum</i>)	41
Red Maple (<i>Acer rubrum</i>)	37
Eastern Redbud (<i>Cercis canadensis</i>)	17
Black Locust (<i>Robinia pseudoacacia</i>)	4
Sweet Crabapple (<i>Malus coronaria</i>)	3
Staghorn Sumac (<i>Rhus hirta</i>)	2
Smooth Sumac (<i>Rhus glabra</i>)	1

Appendix XIII. Approximately 1,680 m of deer fencing would need to be erected prior to planting the hardwood saplings in the treatment area.

