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CHANGES IN FOREST UNDERSTORY COMPOSITION FROM 1970 TO 2003 AT THE GORDON NATURAL AREA, AN URBAN PRESERVE IN CHESTER COUNTY, PENNSYLVANIA[1]

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ABSTRACT

A 2003 survey of woody saplings and seedlings at the Gordon Natural Area in Chester County, Pennsylvania was used for comparison with a survey conducted there in 1970 to determine what changes in forest understory composition have occurred over this thirty-three year period. Plots were established in 2003 in the same forest at the natural area as that surveyed in 1970 and all trees (> 12.6 cm DBH), saplings (between 2.5–12.6 cm DBH), and seedlings (< 2.5 cm DBH and taller than 30.5 cm) were identified and inventoried using size classes similar to those used in 1970. In 2003, the canopy was dominated by tuliptree (*Liriodendron tulipifera*) and American beech (*Fagus grandifolia*). The understory was dominated by *F. grandifolia* and Norway maple (*Acer platanoides*) saplings and by *F. grandifolia* and white ash (*Fraxinus americana*) seedlings, all of whose densities were similar to those found in 1970. Flowering dogwood (*Cornus florida*) and mockernut hickory (*Carya tomentosa*) sapling density decreased from 1970 to 2003 while *C. florida*, ironwood (*Carpinus caroliniana*), and red oak (*Quercus rubra*) seedlings, all present in 1970, were absent from plots in 2003. Two new exotic species, tree of heaven (*Ailanthus altissima*) and princess tree (*Paulownia tomentosa*), were found in the understory in 2003, although at low densities. While canopy dominance by natives did not change from 1970 to 2003, understory forest composition is changing to include fewer native, but more exotic species.
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INTRODUCTION

Extensive deforestation has reduced forest cover in southeastern Pennsylvania since the time of William Penn when the region was covered by forests (Gordon 1941, Overlease 1987, Matlack 1997). Today, much of the region is continuing to experience deforestation due to extensive changes in land use such as urbanization (Matlack 1997, Moyer 2003). Chester County, west of Philadelphia, for example, has lost 24% of forest cover since 1978, and is predicted to lose 51% of that remaining over the next 20 years (American Forests 2003). Thus, remaining forests in this region could disappear or fragment into patches subject to reproductive isolation, increased herbivory and exotic plant encroachment (Hill 1985, Brothers and Spingarn 1992, Yahner 1995).

Promotion of forest conservation in this region is needed since remnant forests can contain a semblance of former composition and community structure and provide ecosystem services such as carbon storage and soil retention (Sukopp et al. 1995, Guntenspergen and Levenson 1997). Because of the predicted high degree of forest fragmentation (American Forests 2003), significant changes in species composition may occur in these fragmented forests. While studies have focused on changes in second-growth composition in rural Pennsylvania forests (Tilghman 1989, PA Bureau of Forestry 1991, Yahner et al. 1992), few have examined forest change in suburban and urban areas of the state for composition and recruitment patterns over time, key measures necessary for refining management strategies of these forests.

One forest that has been studied in an urban area of southeastern Pennsylvania is found at the Gordon Natural Area (GNA), in Chester County. This preserve has been protected from development since 1973, after it was surveyed for tree composition in 1970 (Overlease 1973). We used results from that survey to compare with results from a survey we conducted in 2003 to determine whether woody understory composition has changed since then. We hypothesized that regeneration by native tree species, many of which are canopy dominants, has declined in the understory from 1970 to 2003, while recruitment by exotic species has increased. We also hypothesized that native species richness has declined over this time period due to native species losses in the understory. The ultimate goal of this comparative study is to use the results to better monitor and manage forest composition at the GNA into the future.

STUDY AREA

The Robert B. Gordon Natural Area is a 68 ha preserve located south of West Chester, in Chester County, PA, (39°

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58'N, 75° 38'W) (Figure 1). It lies in the Piedmont physiographic region overlying schist and serpentine slates (Overlease 1973), which are overlain with porous, loamy, soils (Soil Conservation Service 1973). The terrain is hilly, with a northwest aspect and maximum elevation of 30.5 m a.s.l. (Overlease 1973). Annual precipitation averages 185 cm and temperatures range from 6–18 °C (PA State University 2005). It is located at the central broadleaf and southern oak-pine forest boundary (Yahner 1995) and contains forest grown on abandoned farmland (Matlack 1997). William Darlington, who made the earliest botanical survey of the area in 1837 (Stone 1945), described "rich woodlands" teeming with oaks (*Quercus* spp.), tuliptree (*Liriodendron tulipifera*), and sugar maple (*Acer saccharum*). There are no records of fire or other major disturbances at the GNA since 1935, other than chestnut blight (*Cryphonectria parasitica*) (Overlease 1973). The forest overstory is even-aged, approximately 140-years-old (Overlease 1965, unpublished data), and is composed primarily of mid-to-late successional native hardwood species.

METHODS

In 2003, seven plots were randomly established in the GNA hardwood forest using procedures described by McRoberts et al. (2005) (Figure 1). Each plot consisted of three 175 m^2 circular subplots, located equidistant around an identical central subplot, for a total sampling area of 0.49 ha. These plots were located in the same forest area as those used in 1970 though our overall sample-plot location and design differed from Overlease (1973) who used 400 m^2 rec-

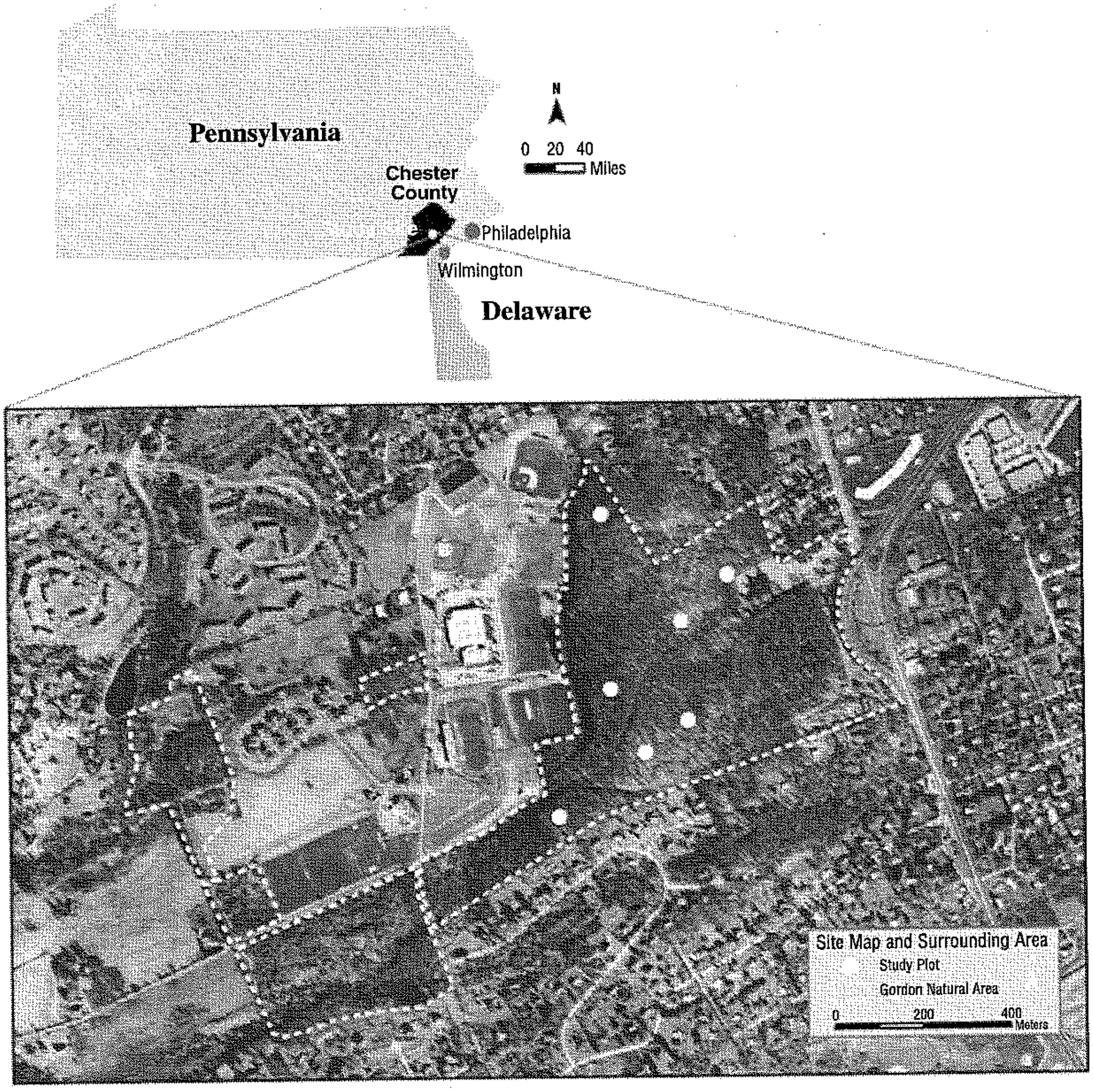

Figure 1. Map of Chester County, Pennsylvania and the Gordon Natural Area forest study plots in 2003.

tangular plots (total area = 0.24 ha) and 100 m^2 square plots (total area = 0.10 ha) to sample saplings and seedlings, respectively. While our plot dimensions are relatively comparable to the plot area sampled in 1970, we did not know the exact location of plots used by Overlease (1973). But, given the small area of the GNA forest, we suggest that our plots were located in close proximity to those used in 1970 and are, thus, comparable. We identified all woody plants using Rhodes and Block (2000), measured each for diameter at breast height (DBH), and classified them as canopy trees (DBH > 12.6 cm), saplings (between 2.5–12.6 cm DBH), or seedlings (DBH < 2.5 cm and stem height > 30.5 cm), as was done in 1970. Within each plot all trees, saplings, and seedlings were counted to determine canopy and understory species densities and richness. Density was calculated as the sum of the individual trees, saplings, and seedlings per plot expressed in stems per hectare. Canopy trees were quantified using % crown cover in 1970, and are thus not comparable to the density calculations made in this study. Species richness was calculated as the total number of tree, sapling, and seedling species present within each plot and across plots collectively, as in 1970. Chi-square tests were conducted to test for potential differences in total sapling and seedling densities and for densities of individual sapling and seedling species found in 1970 and 2003. Effects were considered significant if $P < 0.05$.

Table 1. Total species-specific densities (stems ha^{-1}) of canopy trees in 2003 and saplings and seedlings in 1970 and 2003 at the Gordon Natural Area, Chester County, PA.

Species	Trees	Saplings		Seedlings	
	2003	1970	2003	1970	2003
American beech (*Fagus grandifolia*)	35+	223*	159	215*	106
Black cherry (*Prunus serotina*)	0	75*	22	0	0
Black gum (*Nyssa sylvatica*)	4+	57*	2	200*	4
Black oak (*Quercus velutina*)	6+	17*	0	0	0
Black walnut (*Juglans nigra*)	2	0	0	0	0
Flowering dogwood (*Cornus florida*)	0+	779*	24.5	1319*	0
Ironwood (*Carpinus caroliniana*)	0	74*	16	127*	0
Mockernut hickory (*Carya tomentosa*)	6+	279*	8	108*	6
Norway maple (*Acer platanoides*)	22+	70*	45	108*	16
Pignut hickory (*Carya glabra*)	4+	0	0	0	0
Princess tree (*Paulownia tomentosa*)	2+	0	0	0	4*
Red maple (*Acer rubrum*)	22+	43*	2	350*	2
Red oak (*Quercus rubra*)	24.5+	6*	0	19*	0
Shagbark hickory (*Carya ovata*)	2+	0	0	0	0
Slippery elm (*Ulmus rubra*)	0	0	10*	0	0
Sugar maple (*Acer saccharum*)	0	4*	0	0	0
Sweet cherry (*Prunus avium*)	2	0	2*	219*	4
Tree of heaven (*Ailanthus altissima*)	2	0	0	0	24.5*
Tuliptree (*Liriodendron tulipifera*)	82+	22*	0	15*	4
White ash (*Fraxinus americana*)	31+	133*	4	303*	153
White oak (*Quercus alba*)	0+	8*	0	0	0
Total	247	1538*	296	2983*	324.5

(+) Tree present in the canopy in 1970, but measured for % canopy cover, not density. Canopy cover for *Carya* was not specified to species, but lumped under genus in 1970.

*$P < 0.05$

RESULTS

Fifteen canopy tree species were identified in our plots in 2003, one more than was found in 1970. However, canopy tree richness was likely similar between studies given the fact that *Carya* species were lumped together under the genus in 1970. In the understory, 11 sapling and 10 seedling species were identified in 2003, three and one species fewer, respectively, than found in 1970 (Table 1). While these results may reflect actual differences in richness, it is important to note that the differences in sample-plot location and design mentioned in the Methods section may partially account for these differences. The same may be said for differences in density. Total canopy tree density was 247 trees ha^{-1} in 2003 and was dominated by tuliptree (*Liriodendron tulipifera*), American beech (*Fagus grandifolia*), and white ash (*Fraxinus americana*), which together accounted for 60% of all canopy trees. While not comparable, two of these species, *F. grandifolia* and *L. tulipifera*, were among the dominant trees in the canopy in 1970, based on percent crown cover (Overlease 1973). Total sapling density was significantly lower in 2003 than in 1970 (1538 vs. 296 stems ha^{-1}; $P < 0.05$) as was total seedling density (2983 vs. 324.5 stems ha^{-1}; $P < 0.05$) (Table 1). Decreases in density varied among individual species.

Most notable among sapling densities was the decrease in flowering dogwood (*Cornus florida*), which accounted for over 50% of saplings in 1970, but just 8% in 2003. In comparison, *F. grandifolia* dominated sapling composition in 2003 (54% of saplings), while Norway maple (*Acer platanoides*), *C. florida*, black cherry (*Prunus serotina*), and ironwood (*Carpinus caroliniana*) exhibited relatively higher densities than all other species, and collectively accounted for 36% of sapling density. *L. tulipifera* and red oak (*Quercus rubra*), dominant in the overstory, were absent among saplings in 2003. Conversely, *A. platanoides* saplings, while less abundant in the canopy, had a higher relative density than all other sapling species except beech. Only two native species, slippery elm (*Ulmus rubra*) and sweet cherry (*Prunus avium*), were recorded as new species among saplings in 2003. The changes in sapling density for individual species between 1970 and 2003 was supported by chi-square test results for observed versus expected differences in density for each sapling species between 1970 and 2003, which revealed significant differences for all species ($P < 0.05$) (Table 1).

The sharp reduction in total seedling density from 1970 to 2003 was largely due to reduced *C. florida* density. This species was present in all plots in 1970 and represented 87% of all seedlings then, but was absent from plots in 2003 (Table 1). *L. tulipifera*, red maple (*Acer rubrum*), *P. avium*, and black gum (*Nyssa sylvatica*) were also more abundant in 1970. In comparison, seedling density in 2003 was dominated by *Fraxinus americana* and *Fagus grandifolia*, which together accounted for 80% of all seedlings. Of the remaining seedling species, the exotics *A. platanoides*, tree of heaven (*Ailanthus altissima*), and princess tree (*Paulownia tomentosa*) collectively represented 14% of seedlings in 2003 and were more abundant than all but three native species. This is interesting given the absence of *A. altissima* and *P. tomentosa* seedlings in 1970. Chi-square tests for observed versus expected differences in density for seedling species between 1970 and 2003, like most saplings, resulted in significant differences for all seedling species ($P < 0.05$) (Table 1).

DISCUSSION

As expected, understory composition changed at the GNA forest from 1970 to 2003 with reduced densities and richness for most native species and increased exotic species richness in the understory. Canopy tree richness remained relatively unchanged from 1970, suggesting that overstory composition may be stable and in a mid-to-late successional steady state typical for a 140-year old forest. The changes in understory composition from 1970 to 2003 may partly reflect minor successional change in the GNA forest that has led to reduced densities of shade intolerant species like tuliptree (*Liriodendron tulipifera*). However, it is more likely that the sharp decreases in native understory species densities primarily reflect extensive flowering dogwood (*Cornus florida*) decline caused by the dogwood anthracnose fungus (*Discula destructiva*) (G. D. Hertel pers. comm.) and intense deer browsing, though competitive replacement of native by exotic species may also be a contributing factor.

Reduced native understory densities were high for virtually every reported species from 1970 to 2003 and are reflected in the paucity of forest floor vegetation at the GNA forest. Decreased *C. florida* abundance was evident among both saplings and seedlings and was likely caused by anthracnose disease, as mentioned above, which has been documented at the GNA forest (G. D. Hertel pers. comm.) and in other regional urban forests (Hibben and Daughtrey 1988, White et al. 1990, Carr and Banas 2000). As stated above, reduced *L. tulipifera* density may partly reflect successional replacement of this shade-intolerant species as the forest aged from 1970 to 2003, but we suspect that white-tailed deer (*Odocoileus virginianus*) browsing was a factor contributing to its decreased density. Reduced oak (*Quercus* spp.) density was also evident in this study and corroborates studies of other forests reporting reduced *Quercus* species densities in forest understories (Mikan et al. 1994, Abrams et al. 1995). While fire suppression and poor competitive ability are speculated as contributing to reduced *Quercus* abundance (Bowles & Campbell 1993), we suspect that deer browsing is a likely contributing factor at the GNA forest. Also interesting was our finding of decreased red maple (*Acer rubrum*) density from 1970, since this species has become increasingly abundant in Pennsylvania and in eastern U.S. forests (Abrams 1998, PA Department of Conservation and Natural Resources 2004). Although deer browsing of *A. rubrum* in the understory has not been observed, we suggest that, as for other natives, it is a likely factor influencing the species' reduced density at the GNA.

Conversely, the reduction in American beech (*Fagus grandifolia*) density is an interesting study outcome since it is the only late successional species not to be reduced sharply in the understory. *F. grandifolia* persistence may reflect known resistance to deer browsing (Liang and Seagle 2002), which has been shown in other Pennsylvania forests (Tilghman 1989, Yahner 1995). This species' persistence in the GNA forest understory suggests that it may become more dominant there since other late successional species, such as hickories (*Carya*) and *Quercus*, are not regenerating. Finally, and also of interest, is the contrast between white ash (*Fraxinus americana*) sapling and seedling densities. Higher *F. americana* seedling density, compared to that of saplings, may reflect reduced shade tolerance by its seedlings as they grow into saplings (Burns and Honkala 1990) or reflect abundant seed production and germination resulting in high seedling abundance (G. D. Turner pers. comm.) that later succumbs to deer browsing. Further study of possible deer browsing on *F. americana* and other less abundant native understory species is needed to help determine its potential influence on native recruitment at the GNA.

In contrast to reduced understory native richness, increased exotic richness supports our expectation of increased exotic presence from 1970 to 2003, and corroborates studies of other regional urban forests reporting exotic recruitment (Cypher et al. 1986, Yahner et al. 1992, Wyckoff and Webb 1996). Norway maple (*Acer platanoides*), the sole exotic species found in the understory in 1970, had lower comparable density in 2003, but was still the second densest sapling, while tree of heaven (*Ailanthus altissima*) and princess tree (*Paulownia tomentosa*) were first reported in the understory in 2003. Their recruitment may reflect factors benefiting exotic over native species such as competitive life history strategies (e.g., high seed set and rapid seedling growth) and enhanced seed dispersal along road and trail edges that can favor exotic plant growth and survival (Brothers and Spingarn 1992, Tyser and Worley 1992). Further study is needed at the GNA forest to investigate the plausibility of these assertions.

The GNA contains one of the few urban forests in Chester County, and southeastern Pennsylvania, to have been the focus of ongoing ecological study, but no compositional forest survey has been conducted there for over 30 years. Thus, this study contributes compositional data on species presence and abundance at this forest, which may benefit area researchers interested in management of forest fragments similar in scope to the GNA. Such comparative studies are infrequent and we benefited from having comparative data from Overlease (1973) at our convenience. Ultimately, the study helped us to determine that the GNA forest understory has changed from 1970 to 2003 with reduced presence by many native species and increased exotic species presence. In order to prevent further reductions in native species at the GNA, and especially the loss of dominant canopy species, efforts to improve native recruitment and survival, while excluding exotics, will be needed. The continued monitoring of native and exotic recruitment should help us to address these management goals at this protected urban preserve.

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