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A Comparison of Lowland and Upland Forests of Fairy Stone State Park, Virginia. I. Vascular Plants

Todd S. Fredericksen[1] and Mavrik Mann

School of Natural Sciences and Mathematics
Ferrum College
Ferrum, Virginia 24408

ABSTRACT

Vascular plant community species composition and richness were measured in forests in lowland and upland topographic positions at Fairy Stone State Park, Patrick County, Virginia. Species richness was significantly higher in the lower (herbaceous plant level) and middle (shrub level) layers of lowland forests, but species richness in the upper (trees $\geq$10 cm diameter at breast height) layer did not differ between forest types. Upland forests tended to have higher stem density in the upper layer, but lower mean diameter-at-breast height. Tuliptree (*Liriodendron tulipifera*) was the most abundant species in the upper layer of lowland forests, while Sourwood (*Oxydendrum arboreum*) and oaks (*Quercus* spp.) were predominant in the upper layer of upland forests. Red Maple (*Acer rubrum*), White Oak (*Quercus alba*), and White Pine (*Pinus strobus*) were abundant in both forest topographic positions. Mountain Laurel (*Kalmia latifolia*), White Pine, and Red Maple were common species in the middle layer of both forest types, while American Beech (*Fagus grandifolia*) was also abundant in the middle layer of lowland forests. Japanese Stiltgrass (*Microstegium vimineum*), an invasive exotic species, was by far the most common species in the lower layer of lowland forests, while Blue Ridge Blueberry (*Vaccinium pallidum*) was the most common species in the lower layer of upland forests.

Key words: forest plant communities, biodiversity, topography, Blue Ridge Mountains.

INTRODUCTION

Numerous factors affect plant species composition in forests, including light availability, soil moisture, nutrients levels, temperature, and environmental disturbances. Many of these factors are linked to topographic variation, including slope position, aspect, and elevation (Desta et al., 2004). In the highly dissected terrain of the upper Piedmont and Blue Ridge physiographic provinces of Virginia, topographic factors play a major role in the structure of plant communities (Johnson & Ware, 1982; Stephenson, 1982; Farrell & Ware, 1988, 1991; Harrison et al., 1989; Copenheaver et al., 2006; Brown & Fredericksen, 2008), with subsequent impacts on animal communities. Topographic variation leads to differences in soil and air temperature, wind velocity, solar radiation, and humidity. In general, northern aspects, lower slope positions, and low slope inclinations are more mesic than southern aspects, upper slope positions, and steep slope inclinations (Rubino & McCarthy, 2003).

In 2010, we conducted a study comparing the vascular plant and vertebrate animal communities occurring on lowland topographic positions (toeslope and valley positions) and upland topographic positions (shoulder and ridgetop positions) in the forests of Fairy Stone State Park, Patrick County, Virginia. This paper describes the species richness, diversity, and composition, and relative stem density, of vascular plants in lowland and upland slope positions in the forests of the park. A companion paper describes the songbird and terrestrial vertebrate animal communities of these study sites.

STUDY SITE

Fairy Stone State Park is the largest of Virginia's six original state parks. The 1775-ha park in Patrick County is managed by the Virginia Department of

[1]Corresponding author: tfredericksen@ferrum.edu

Conservation and Recreation. Except for recreational areas that are heavily impacted by visitors, the park contains large areas of mature, undisturbed forest. Much of the park has highly dissected terrain with steep slopes and deep valleys characteristic of the foothills of the Blue Ridge Mountains.

In the latest Fairy Stone State Park management plan, one of the priorities is to conduct a biological inventory of the park in order to characterize its biodiversity, identify rare and endangered species, assess conservation threats, and recommend management actions. This information can help park staff manage access to areas that have rare species or species of special concern, as well as to identify areas threatened by invasive plant species.

METHODS

Experimental Design

A forest survey of the park conducted by the Virginia Department of Forestry in 1991 (W.R. Daniel & R.K. Clark, unpublished data) produced a map of forest types characterized by the most abundant species. We used this map to identify sampling areas in the park for two general forest types. The first type, hereafter referred to as "lowland forests", occupied lower slopes and streamsides. Common species include White Pine (*Pinus strobus*), Tuliptree (*Liriodendron tulipifera*), Northern Red Oak (*Quercus rubra*), and American Beech *(Fagus grandifolia*). The second forest type, hereafter referred to as "upland forests", includes species of upper slopes and ridges; common species present include Virginia Pine (*Pinus virginiana*), White Pine, Scarlet Oak (*Quercus coccinea*), and Chestnut Oak (*Quercus montana*). Using the map, as well as aerial photography and ground reconnaissance, we identified sites spread throughout the park with dissected terrain containing upland and lowland slope positions and which were not subjected to recent significant human disturbance (campgrounds, roads, heavily impacted trail areas, or other development). In these areas, we located ten pairs of sampling plots (upland and lowland) at a set distance from an opportunistically located starting position (typically a landmark, such as a trail junction, sign, or boundary marker).

Sampling

Plots were nested to sample different forest strata: upper (composed of overstory and midstory trees $\geq$10 cm dbh), middle (shrubs, vines and trees $\geq$1 m tall, but <10 cm dbh), and lower (herbaceous plants and seedlings of woody plants <1 m tall). Plots for the upper layer were 20 x 50 m in size. Within this plot, all live trees $\geq$10 cm dbh were identified to species and their dbh was measured. Through the center of this plot lengthwise, a 4 x 50 m belt transect for the middle layer was established where all trees, shrubs, and vines >1 m tall, but <10 cm dbh, that were rooted in the plot were counted by species. For the lower layer (plants $\leq$1 m tall), ten 1 x 1 m plots were established along the centerline of the main plot at 5 m intervals. Plants in these plots were counted and identified to species, or genus level if they could not be identified to species. A search of the entire 20 x 50 m main plot was also conducted for any species in any sample layer not included within measured plots to determine overall species richness. Sampling was carried out from June to August 2010. Plant taxonomy followed Wofford (1989).

Data Analysis

The upper layer plot (20 x 50 m) was used as the experimental unit for all data analyses (n=10). Species richness was calculated at the tree layer plot level for the three layers. Stem density was determined for each species in each of the three layer plots. Paired t tests were used for statistical comparisons of species richness and stem density for upland and lowland plots using SYSTAT 12.2 (SYSTAT Software Inc., San Jose, CA). In addition, species composition differences in the upper layer among all plots were explored with detrended correspondence analysis (DCA) using PC-ORD 5 (MJM software, Gleneden Beach, OR).

RESULTS

Plant species richness in the lower layer of lowland forest plots was nearly double that of upland plots ($t = 5.79$, $p < 0.001$; Fig. 1). Middle layer species richness also was significantly higher in lowland compared to upland plots ($t = 2.75$, $p = 0.02$; Fig. 1). Upper layer species richness was similar between upland and lowland plots ($t = 0.26$, $p = 0.80$; Fig. 1).

In the upper layer, upland forests had more trees in the smaller diameter classes than lowland forests, whereas lowland forests had a higher density of large trees (Fig. 2). The median DBH of all trees was higher in lowland plots (22.5 cm) than upland plots (20.0 cm). The mean number of trees per plot was higher in upland forests ($t = 3.24$, $p = 0.01$, Table 1).

Tuliptree was, by far, the most abundant species in the lowland plots, often occurring as a canopy tree species (Table 1). An understory tree, Sourwood (*Oxydendrum arboreum*), was the most abundant tree

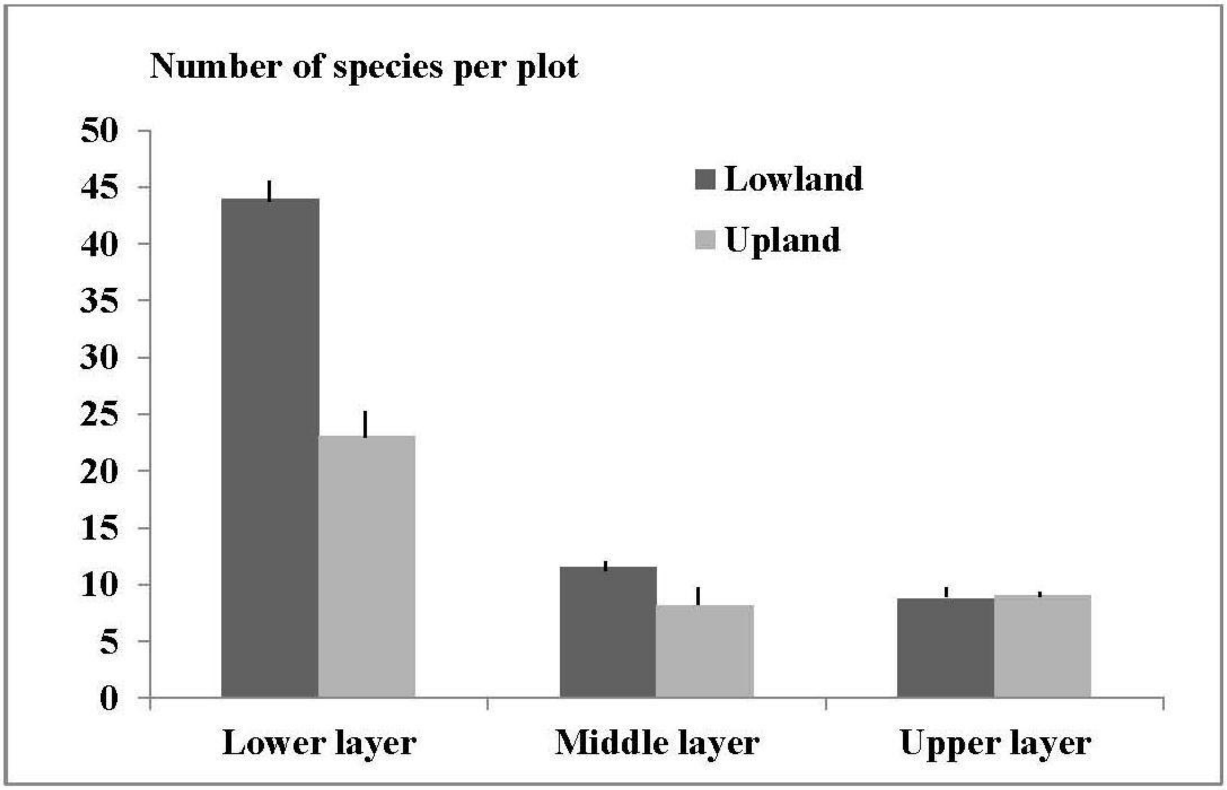

Fig. 1. Mean (+ standard error) species richness of plants in the lower layer (<1 m tall), middle layer (>1 m tall but <10 cm DBH), and upper layer ($\geq$10 cm DBH) in lowland and upland forests at Fairy Stone State Park, Patrick County, Virginia.

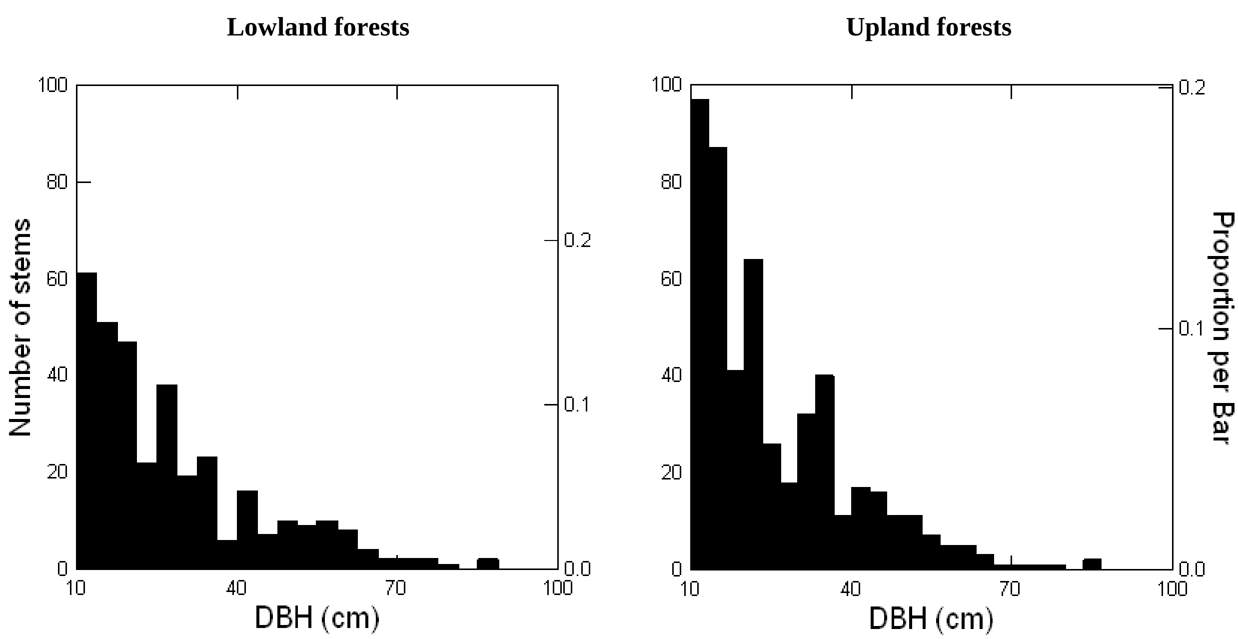

Fig. 2. Diameter distribution of trees $\geq$10 cm (dbh) in lowland and upland forests of Fairy Stone State Park, Virginia.

Table 1. Mean number of stems/ha for species in the upper layer (≥10 cm DBH) in lowland and upland forests of Fairy Stone State Park, Virginia.

Lowland forests		**Upland forests**	
Species	**#/ha**	**Species**	**#/ha**
Liriodendron tulipifera	88	*Oxydendrum arboreum*	89
Acer rubrum	42	*Acer rubrum*	68
Quercus alba	37	*Quercus montana*	65
Oxydendrum arboreum	28	*Quercus alba*	65
Pinus strobus	27	*Pinus strobus*	63
Fagus grandifolia	19	*Liriodendron tulipifera*	33
Betula lenta	17	*Quercus coccinea*	33
Nyssa sylvatica	12	*Nyssa sylvatica*	19
Cornus florida	12	*Quercus velutina*	12
Carya glabra	9	*Carya glabra*	11
Quercus rubra	8	*Carya tomentosa*	10
Carpinus caroliniana	7	*Pinus echinata*	9
Cercis canadensis	7	*Pinus virginiana*	6
Juglans nigra	6	*Pinus rigida*	5
Fraxinus pennsylvanica	6	*Quercus falcata*	3
Carya tomentosa	6	*Fagus grandifolia*	3
Platanus occidentalis	3	*Cornus florida*	2
Magnolia fraseri	2	*Quercus rubra*	1
Sassafras albidum	1	*Magnolia acuminata*	1
Quercus velutina	1	*Betula lenta*	1
Quercus montana	1		
Pinus virginiana	1		
TOTAL	**340**		**499**

species in upland plots, but was also one of the most common species in lowland plots, although it had only about one-third of the stem density as in upland plots (Table 1). Oaks were much more common in upland plots, with a particularly higher abundance of Chestnut Oak and Scarlet Oak. White Oak (*Quercus alba*), was among the most common species in both forest types, although it was approximately twice as abundant in upland plots. Red Maple (*Acer rubrum*) and White Pine were also among the most common species in both forest types, although they had higher stem densities in the upland plots. Species occurring with higher densities in lowland plots included American Beech and Black Birch (*Betula lenta*). Other species occurred only in lowland plots, although at low densities, including American Hornbeam (*Carpinus caroliniana*), Eastern Redbud (*Cercis canadensis*), Green Ash (*Fraxinus pennsylvanica*), American Sycamore (*Platanus occidentalis*), Fraser Magnolia (*Magnolia fraseri*), and Sassafras (*Sassafras albidum*). Two pine species, Shortleaf Pine (*Pinus echinata*) and Pitch Pine (*P. rigida*), only occurred on upland plots. Hickories (*Carya* spp.) occurred with similar abundance in upland and lowland plots.

Detrended correspondence analysis (DCA) of the upper layer data indicated a clear separation between lowland and upland plots along the first axis (Fig. 3), which explained approximately 44% of the variation in the data. Species on the right side of DCA Axis 1 occurred commonly in lowland plots, but not in upland plots. Species that were more abundant in upland plots occurred on the left side of the first axis. DCA Axis 2 explained only 19% of the variation in the data and it was less clear what factors were associated with this axis. One upland plot (plot 18) was isolated from other upland plots on one end of this axis (Fig. 3). This plot was on a ridgetop/south-facing shoulder position and had a high abundance of Scarlet Oak, Shortleaf Pine, and Pitch Pine. For lowland plots, this axis separated American Beech, Green Ash, American Sycamore, and Black Walnut (*Juglans nigra*) from species such as Flowering Dogwood, American Redbud, Black Birch, and American Hornbeam (Fig. 3). Species with intermediate positions relative to these two axes included tree species such as White Pine, Red Maple, and White Oak (Fig. 3) that have wide environmental tolerance. Northern Red Oak also appeared as an intermediate species, presumably because it occurred on upland plots with north-facing slopes and also in lowland plots on toeslope positions.

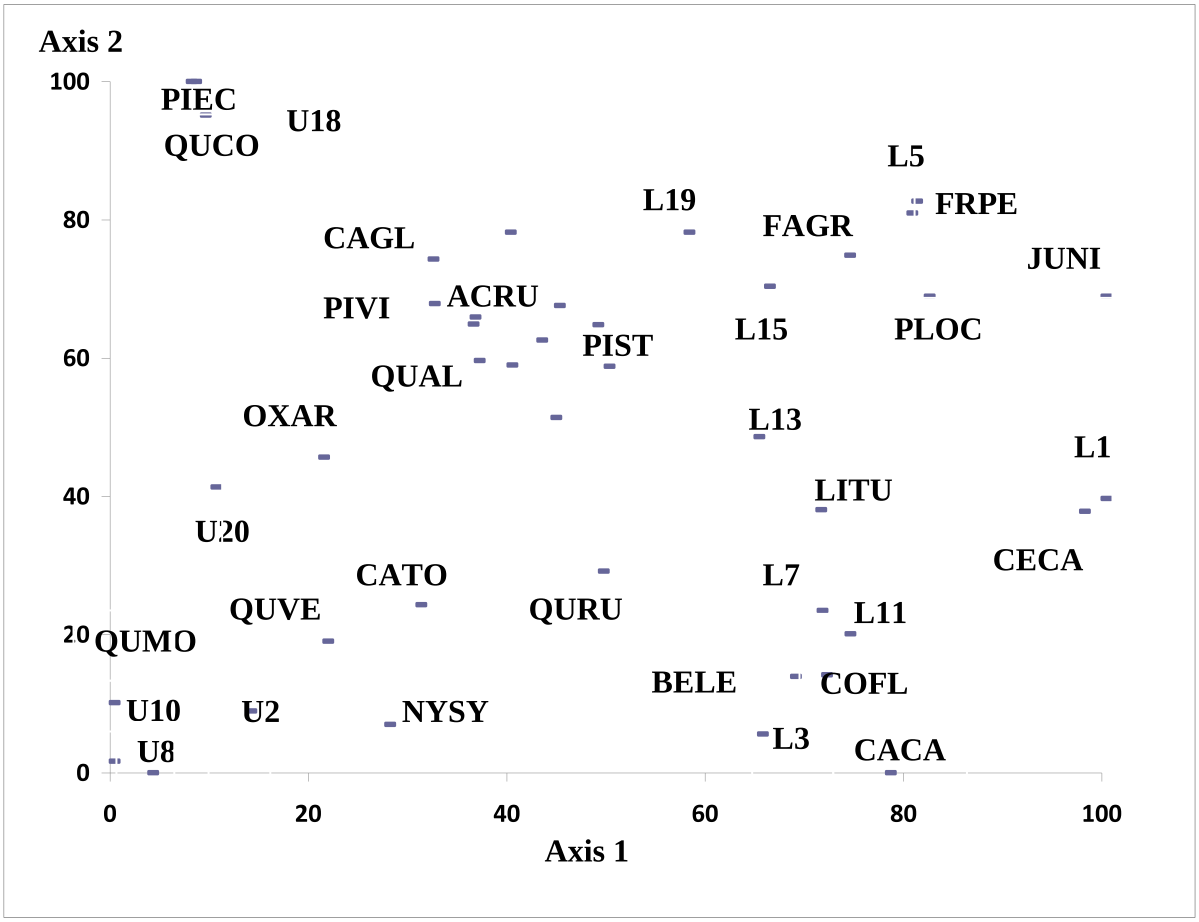

Fig. 3. Detrended correspondence analysis of tree species ≥10 cm dbh and sampling scores along the first and second axes of the ordination. Species codes: ACRU=*Acer rubrum*, BELE=*Betula lenta*, CACA=*Carpinus caroliniana*, CAGL=*Carya glabra*, CATO=*Carya tomentosa*, CECA=*Cercis canadensis*, COFL=*Cornus florida*, FAGR=*Fagus grandifolia*, FRPE=*Fraxinus pennsylvanica*, JUNI=*Juglans nigra*, LITU=*Liriodendron tulipifera*, OXAR=*Oxydendrum arboreum*, NYSY=*Nyssa sylvatica*, PLOC=*Platanus occidentalis*, QUAL=*Quercus alba*, QUCO=*Quercus coccinea*, QUMO=*Quercus montana*, QURU=*Quercus rubra*, QUVE=*Quercus velutina*, PIEC=*Pinus echinata*, PIST=*Pinus strobus*, PIVI=*Pinus virginiana*. Upland and lowland plot scores are noted as "U" and "L" along with the plot number.

Middle layer density did not differ between lowland and upland plots (t = 0.11, p = 0.92; Table 2). American Beech was the most abundant middle layer species in lowland forest plots, but was relatively rare in upland plots. Mountain Laurel (*Kalmia latifolia*) was the most abundant species in this layer in upland plots, and it was also abundant in lowland plots. White Pine and Red Maple were among the most abundant middle layer species for both topographic positions. Species with relatively high abundance in lowland plots, but which did not occur or rarely occurred in the middle layer of upland plots, included American Hornbeam, Great Laurel (*Rhododendron maximum*), and Green Ash. Sourwood, Chestnut Oak, and Blackgum (*Nyssa sylvatica*) had much higher abundances in the middle layer of upland compared to lowland plots.

Lower layer plant density was significantly higher in lowland plots (t = 2.69, p = 0.025; Table 3). By far, the most abundant species in the lower layer of lowland plots was Japanese Stiltgrass (*Microstegium vimineum*), an invasive exotic species commonly occurring in mesic habitats (Table 3). Also abundant in lowland plots were Hay-scented Fern (*Dennstaedtia punctilobula*) and seedlings of Green Ash. The most abundant species in upland plots was Blue Ridge Blueberry (*Vaccinium pallidum*) (Table 3). Seedlings of Red Maple, White Pine, and Mountain Laurel were abundant in both forest types. Seedlings of Black Birch (*Betula lenta*) and Tuliptree were abundant on lowland plots.

Table 2. Mean number of stems/ha for species in the middle layer (<10 cm DBH, but ≥1 m in height) in lowland and upland forests of Fairy Stone State Park, Virginia.

Lowland forests		**Upland forests**	
Species	**#/ha**	**Species**	**#/ha**
Fagus grandifolia	540	*Kalmia latifolia*	710
Kalmia latifolia	450	*Pinus strobus*	565
Pinus strobus	370	*Acer rubrum*	440
Carpinus caroliniana	180	*Oxydendrum arboreum*	150
Acer rubrum	140	*Quercus montana*	90
Rhododendron maximum	125	*Nyssa sylvatica*	85
Cornus florida	65	*Cornus florida*	35
Fraxinus pennsylvanica	50	*Fagus grandifolia*	20
Oxydendrum arboreum	45	*Ilex opaca*	20
Ilex opaca	35	*Quercus alba*	20
Magnolia fraseri	20	*Magnolia acuminata*	15
Quercus montana	20	*Carya glabra*	10
Hamamelis virginiana	15	*Betula lenta*	10
Cercis canadensis	15	*Cercis canadensis*	10
Acer saccharum	10	*Quercus coccinea*	10
Betula lenta	10	*Quercus rubra*	5
Quercus velutina	10	*Quercus velutina*	5
Carya cordiformis	10	*Castanea dentata*	5
Lindera benzoin	10	*Vaccinium corymbosum*	5
Nyssa sylvatica	10	*Carya tomentosa*	5
Carya glabra	10	*Carpinus caroliniana*	5
Vaccinium stamineum	5	*Acer saccharum*	5
Carya tomentosa	5		
TOTAL	**2150**	**TOTAL**	**2225**

Table 3. Mean number of stems/m^2 for species in the lower layer (<1 m tall) in lowland and upland forests of Fairy Stone State Park, Virginia.

Lowland forests		**Upland forests**	
Species	**#/m^2**	**Species**	**#/m^2**
Microstegium vimineum	4.73	*Vaccinium pallidum*	0.84
Fraxinus pennslyvanica	1.61	*Acer rubrum*	0.77
Dennstaedtia punctilobula	1.58	*Smilax* spp.	0.67
Potentilla canadensis	1.30	*Pinus strobus*	0.35
Viola spp.	1.16	*Kalmia latifolia*	0.32
Betula lenta	1.00	*Galax urceolata*	0.25
Acer rubrum	0.79	*Quercus montana*	0.24
Liriodendron tulipifera	0.68	*Quercus velutina*	0.18
Smilax spp.	0.67	*Chimaphila maculata*	0.15
Kalmia latifolia	0.50	*Quercus alba*	0.11
Galium spp.	0.42	*Viola* spp.	0.08
Pinus strobus	0.39	*Galium* spp.	0.08
Hepatica americana	0.35	*Carex* spp.	0.08
Ranunculus spp.	0.34	Others	0.95
Mitchella repens	0.28		
Cercis canadensis	0.25		
Euonymus americanus	0.24		
Galax urceolata	0.19		
Fagus grandifolia	0.19		
Anemone quinquefolia	0.17		
Chimaphila maculata	0.15		
Polystichum acrostichoides	0.15		
Others	2.10		
TOTAL	**19.5**	**TOTAL**	**5.5**

DISCUSSION

The higher lower and middle layer species richness of lowland compared to upland plots may be due to higher moisture conditions on these sites. Other studies have found greater understory plant richness and cover on more mesic slope positions (Heubner et al., 1995; Hutchinson et al., 1999; Small & McCarthy, 2005). On drier, upland sites, moisture and nutrient limitations may restrict plant cover and species richness. The higher species richness on lowlands was somewhat compromised, however, by the high relative abundance of Japanese Stiltgrass. This species commonly invades mesic sites and is spread through seed dispersal by streams and rivers (Barden, 1987). While the middle layer of lowland plots had a higher average number of species per plot, total middle layer species richness of lowland and upland plots differed by only one species. Gilliam (2007) noted that species-rich herb layers generally occur in areas with species-rich overstories. Mean tree layer species richness did not differ, however, between lowland and upland plots, although there were four more tree species on lowland sites when summed over all plots.

Structural differences in tree density and diameter distribution were observed between upland and lowland plots, with a higher density on upland plots and a larger mean diameter on lowland plots. This pattern was also observed in studies by Desta et al. (2004) and Brown & Fredericksen (2008). Desta et al. (2004) noted that tree density may be higher on more xeric sites due to a more open canopy, as well as a slower process of competitive exclusion of stems compared to lowland sites. The better growing conditions and lower density on lowland sites may also contribute to larger stem diameters.

It is interesting to note that both topographic positions shared five of the six most common upper layer species, including Tuliptree, Red Maple, White Oak, White Pine, and Sourwood. However, the mean density and abundance rank of these species differed dramatically. For example, there was an almost inverse shift in the density and abundance rank of Tuliptree (the most abundant species on lowland plots) and Sourwood (the most abundant species on upland plots). Red Maple, White Oak, and White Pine are largely considered to be generalist species (Abrams, 1998, Elliott et al., 1999). These species also occurred in the center of the DCA ordination, suggesting that they are generalists along the spectrum of species sampled in this study. Elliott et al. (1999) also considered Sourwood, Chestnut Oak, and Blackgum to be habitat generalists in the southern Appalachians, but these species were much more abundant on upland sites in our study. Brown & Fredericksen (2008) also found these species to be associated with sideslope and shoulder positions on a study site in Franklin County, Virginia. There was a clear separation in the DCA ordination between species occurring on drier upper slopes (ridgetops and south-facing upper slopes), which had high abundances of Scarlet Oak, Shortleaf Pine, and Pitch Pine, and other upper slope positions which contained more Chestnut Oak, Black Oak, Blackgum, and Mockernut Hickory. While Tuliptree was much more abundant on lowland sites (Harrison et al., 1989; Elliott et al., 1999; Brown & Fredericksen, 2008), it was somewhat surprising to see this species rank so high in abundance on upland sites, although plots located on north- and east-facing upper slopes provide the mesic habitat conditions required by this species.

The upland forests in the Blue Ridge Mountains of Virginia were once dominated by American Chestnut (*Castanea dentata*) until the invasion of the Chestnut Blight fungus (*Endothia parasitica*) in the 1920s (Johnson & Ware, 1982). Sprouts of American Chestnut were occasionally found in the sample plots of this study. Following the loss of Chestnut, highest rankings of density and basal area in upland forests have been shared by a number of tree species, predominantly oaks and hickories (Johnson & Ware, 1982). While oak species were more abundant in upland plots, hickories had a similar abundance in upland and lowland plots.

Except for a large ice storm in 1994, the forests of Fairy Stone State Park have been largely undisturbed, as evidenced by large-diameter trees and closed-canopy forests. An abundance of White-tailed Deer (*Odocoileus virginianus*) in the park may have impacted forest understory plant abundance and species composition because there was evidence of browsing in many sample plots. The abundance of Tuliptree, particularly on lowland plots in this study, is probably a legacy of high recruitment on sites following the abandonment of cultivation. The species is a long-lived pioneer adapted to germination on scarified soil and rapid growth under full sunlight (Beck, 1990). The shaded understory of both upland and lowland plots, along with dense low shade created by Mountain Laurel (primarily on upland sites) and Rhododendron (primarily on lowland sites), may inhibit recruitment of Tuliptree into the middle layer.

In the continued absence of disturbance, it appears that the species composition in the upland plots in the park will shift towards a higher abundance of Red Maple and White Pine, as evidenced by the abundance of these species in the middle and lower layers. Red Maple, in particular, has been observed to have high recruitment and increasing abundance in the understories of oak forests in the eastern U.S. (Lorimer, 1984; Abrams & Downs, 1990; McEwan et al., 2005). While there were some plots with oak regeneration in the lower layer, advancement to the middle layer appears to be limited. White Pine was abundant in all layers of both upland and lowland forests, although it tended to be more abundant in the upper and middle layer of upland forests. Copenheaver et al. (2006) found that White Pine had higher recruitment on younger, mid-slope stands on a site in the Ridge and Valley Province of Virginia. The successful recruitment of White Pine into the middle layer at Fairy Stone State Park may be a result of the 1994 ice storms that probably created a more open canopy through damage to overstory tree crowns.

As with upland plots, shifts in species composition on lowland plots also seem likely in the future, changing from current dominance by Tuliptree, which shows limited recruitment in the understory, towards American Beech, White Pine, and Red Maple. This pattern, observed in both lowland and upland plots, lends support to the “mesophication” hypothesis of eastern hardwood forests (Nowacki & Abrams, 2008), with species adapted to mesic sites increasing at the expense of oaks and other xeric species. This trend in mesophication is largely attributed to fire exclusion (Nowicki & Abrams, 2008; Martin et al., 2011).

In lowland forests, Black Birch and Green Ash also had abundant seedling regeneration, but there does not appear to be much success for these species in recruitment to the middle layer. The high density of Japanese Stiltgrass in lowland forest plots is also likely to negatively affect the establishment of tree species in these forests, as well as decrease plant diversity. Few other exotic species were found in plots during this study because they were located in interior forests where it is difficult for invasive species to become established (Gilliam, 2007). We observed patches of invasive exotic species, however, in other areas of the park along edges and disturbed areas including Tree-of-heaven (*Ailanthus altissima*), Japanese Honeysuckle (*Lonicera japonica*), Chinese Privet (*Ligustrum sinensis*), Periwinkle (*Vinca minor*), Wisteria (*Wisteria sinensis*), Autumn Olive (*Elaeagnus umbellata*), and Princess Tree (*Paulownia tomentosa*).

While there were some clear differences in species richness and composition in this study between upland and lowland forests, considerable extraneous variation can make interpretation of these data difficult. First, there were too few sample plots in the study to quantitatively determine the influence of aspect and slope angle on these plant communities. In addition, the variations in microtopography among lower slope and upland sites, along with associated microclimatic elements, could have led to additional unexplained variation in the data. These factors, along with the interrelationship between topography and land use history, can make it difficult to determine the full extent of the influence of topography on plant communities (Harrison et al., 1989).

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Appendix 1. GPS coordinates of sampling plots in decimal degrees. Asterisks indicate permanent sampling plots for trees >10 cm dbh.

Plot number	Topographic position	Coordinates	Location description
1*	Lowland	36.79796, -80.11835	Southwest of Stuart's Knob parking area
2*	Upland	36.79780, -80.12000	Uphill from plot 1, 100 m North of beach overlook
3*	Lowland	36.78835, -80.11546	Valley behind water treatment pond across from picnic area
4*	Upland	36.79938, -80.11621	50 m South of maintenance storage area
5*	Lowland	36.80567, -80.11215	Road to dam on right just after first curve to left
6*	Upland	36.80610, -80.11318	On shoulder ridge West of plot 5
7*	Lowland	36.77776, -80.10036	In cove, South from paved trail, 150 m from Goose Point Road
8*	Upland	36.77896, -80.09739	North of paved trail, 50 m from Goose Point Road
9	Lowland	36.78299, -80.09719	Little Mountain Falls Trail North of Plot 10 on right side past first creek
10	Upland	36.78117, -80.10040	Little Mountain Falls Trail on left just past half-way point marker
11	Lowland	36.79286, -80.11106	Oak-hickory Trail near roads and trails interpretative sign
12	Upland	36.78973, -80.11251	Oak-hickory Trail, 200 m South of trailhead
13	Lowland	36.79573, -80.10659	Lakeshore Trail, along ephemeral stream near pavilion
14	Upland	36.79722, -80.10496	100 uphill from junction of Lakeshore and Turkey Ridge Trail
15	Lowland	36.78519, -80.11249	Crossover Trail on right 250 m from Little Mountain Falls Trail
16	Upland	36.78760, -80.11688	Little Mountain Falls Trail on right 200 m from juncture with Crossover Trail
17	Lowland	36.77250, -80.10625	North of State Road 57, along stream West of Plot 18
18	Upland	36.77109, -80.10401	North of State Road 57, near sign for Rt. 822
19	Lowland	36.81448, -80.11343	Fairy Stone Park Road, left side 150 m South of Park Boundary Road Gate
20	Upland	36.81538, -80.11236	Park Boundary Road off Fairy Stone Park Road – 150 m on right

Appendix 2. List of additional rarely encountered species occurring within sampling plots, but not listed in Tables 1-3.

Lowland forests

Adiantum pedatum
Ailanthus altissima
Agrimonia spp.
Ambrosia artemisiifolia
Amelanchier arborea
Arisaema triphyllum
Asimina triloba
Asplenium montanum
Botrychium dissectum
Carex spp.
Chrysogonum virginianum
Castanea dentata
Claytonia virginica
Crataegus spp.
Cymophyllus fraseri
Cynoglossum virginianum
Cyperus spp.
Dentaria lacinata
Desmodium spp.
Dioscorea villosa
Diospyros virginiana
Dryopteris spp.
Elaeagnus umbellata
Galax urceolata
Geranium maculatum
Goodyera pubescens
Hepatica acutiloba
Hexastylis virginica
Hieracium venosum
Houstonia caerulea
Iris cristata
Juniperus virginiana
Ligustrum sinense
Lonicera japonica
Lycopodium lucidulum
Magnolia acuminata
Magnolia tripetala
Medeola virginiana
Menispermum candense
Monotropa uniflora
Orchis spectabilis
Osmunda cinnamomea
Oxalis stricta
Panicum spp.
Parthenocissus quinquefolia
Pinus echinata
Podophyllum peltatum
Prenanthes serpentaria
Rhododendron calendulaceum
Rhus radicans
Rhynchospora capitellata
Rubus spp.
Sanguinaria canadensis
Silene virginica
Smilacina racemosa
Solidago spp.
Symplocarpus foetidus
Thalictrum thalictroides
Tiarella cordifolia
Trifolium spp.
Trillium grandiflorum
Urtica dioica
Uvularia perfoliata
Uvularia sessilifolia
Verbesena alternifolia
Viburnum acerifolium
Viburnum prunifolium
Vinca minor
Vitus labrusca

Upland forests

Ailanthus altissima
Amelanchier arborea
Antennaria spp.
Asplenium spp.
Castanea dentata
Conopholis americana
Cynoglossum virginianum
Desmodium spp.
Dioscorea villosa
Diospyros virginiana
Euonymus americana
Fraxinus americana
Goodyera pubescens
Hamamelis virginiana
Hexastylis virginica
Hieracium venosum
Hypericum hypericoides
Juniperus virginiana
Medeola virginiana
Microstegium virmineum
Monotropa uniflora
Oxalis stricta
Panicum spp.
Parthenocissus quinquefolia
Polypodium virginianum
Polystichum acrostichoides
Potentilla canadensis
Prenanthes serpentaria
Prunus serotina
Ranunculus spp.
Rhododendron nudiflorum
Rhus radicans
Rhynchospora capitellata
Robinia pseudoacacia
Rubus spp.
Sassafras albidum
Tiarella cordifolia
Thalictrum thalictroides
Uvularia sessilifolia
Viburnum acerifolium
Vitus labrusca