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Spatial pattern in herb diversity and abundance of second growth mixed deciduous-evergreen forest of southern New England, USA

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ABSTRACT

This study was designed to answer questions about the patterns of understory diversity in managed forests of southern New England, and the factors that appear associated with those patterns. At the landscape-level, we used plot data to answer questions regarding the spatial distribution of forest understory plant species. Data from a combination of fixed area (understory vegetation) and variable radius (overstory trees) plot methods are combined with site variables for the analysis. Univariate and multivariate statistical methods are used to test for understory diversity relationships with overstory cover types and topography separately, and in combination. Analyses also test for relationships between specific understory species and cover types. In general the understory flora is dominated by four common clonal species that occur across the range of forest cover types: wild sarsaparilla (*Aralia nudicaulis* L.), Canada mayflower (*Maianthemum candense* Desf.), star flower (*Trientalis borealis* Raf.), and partridgeberry (*Mitchella repens* L.). Results also show that over story composition and structure can be used to assess understory species richness. Species richness follows a general trend among cover types of: hardwood ≥ regenerating forest, hardwood–pine, and pine ≥ mixed ≥ hardwood–hemlock > hem-hemlock. Eastern hemlock (*Tsuga canadensis* L. Carriere) and mountain laurel (*Kalmia latifolia* L.) (which decreased in dominance from ridge to valley) both showed negative trends with understory species richness. Topographic position also appears associated with understory floristic patterns (particularly for the hardwood cover type), both in terms of species richness and compositional diversity which both increased from ridge, to midslope, to valley. However, overstory composition (covertype) appears to have a higher order influence on vegetation and mediates the role of topography. The results from this study provide foresters with a better understanding for maintaining floristic diversity and composition of the understory in managed forests.

1. Introduction

Maintaining diversity in native ecosystems is now recognized as a critical factor for sustainable management for goods and services desired by society (UNEP, 1992; Brooks et al., 2006). Plants are a major component of diversity that is essential for maintaining and regulating ecosystem function (Bormann and Likens, 1979). The largest component of plant diversity in temperate forests is that found in the understory (Whigham, 2004). In temperate forests plant diversity and abundance in the understory plays an important role in contributing to leaf litter and mulch, facilitating decomposition, and in nutrient conservation (Bormann and Likens, 1979). Plants in the understory provide soil surface protection from erosive forces of precipitation and lethal temperatures from radiation (Bormann and Likens, 1979). The understory also takes up nutrients from throughfall and decomposition (Peterson and Rolfe, 1982; Bormann and Likens, 1979; Roberts and Gilliam, 1995).

Forest managers are therefore increasingly concerned with maintaining understory plant diversity while developing and providing timber resources. Identifying indicators of understory plant diversity based on landform and forest cover types could provide managers with an efficient tool that can be combined with standard inventory methods. Such a tool could be used with stand-level inventories for mapping areas of high and low understory plant diversity and of particular species composition. Such stand scale maps can then be used in planning silvicultural operations that are compatible with protecting plant understory diversity and composition. Forest understory composition in central New England was shown to be influenced by both stand age and stand type (Whitney and Foster, 1988), while stand structure was an important factor in northern European deciduous forests

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(Thomsen et al., 2005). For eastern US forests, the relationships between slope position and soil moisture gradients (Huebner et al., 1995) and C/N ratios (Small and McCarthy, 2005) have been shown to affect understory plant community composition. The influences of microtopography (Bratton, 1976; Beatty, 1984) and site characteristics such as litter type and depth and coarse woody debris are also considered important factors in understory plant diversity (Brosofske et al., 2001).

Stand-level variables (e.g. overstory basal area, density and species composition, topographic position) are considered to be the appropriate focus of this study, as the stand is the management unit most often identified when implementing silvicultural prescriptions (Roberts and Gilliam, 1995; Smith et al., 1997). However, very little work to date has looked at stand-level floristic associations between forest overstory and understory vegetation for southern New England mixed hardwood-coniferous forests. This study will identify forest stand variables that can be used to assess understory diversity for southern New England forests.

The objectives of this study are to: (1) identify differences in understory species richness and composition that are associated with overstory composition and basal area, and (2) identify differences in understory species composition that are associated with the combination of overstory composition and topographic variation.

What this study does not do is compare floristic diversity in a managed forest with diversity in unmanaged forests where little to no human impacts have occurred. There is also some limitation to the study, as it was originally designed to monitor long-term floristic changes, rather than to test any specific hypothesis. However, we believe the high number of plots sampled and the sparse amount of information of this type available for southern New England forests overcomes any limitations in original design.

2. Site description

This study was conducted at the Yale-Myers Forest in Windham and Tolland Counties, Connecticut, USA (41°55′N 72°05′W). Yale-Myers Forest covers 3213 hectares in the towns of Ashford, Eastford, Westford, and Union, and is owned by Yale University and managed by The Yale School of Forestry and Environmental Studies for timber production, research, and educational activities.

Growing season for the region averages about 163 days a year, with an annual average daily temperature of 8.7 °C, and about 1090 mm of precipitation relatively evenly distributed throughout the year (USDA, 1981). The coldest month of the year is January, with mean daily high of 2 °C and mean daily low of −11 °C. July is the warmest month, with mean daily high of 28 °C and mean daily low of 14 °C (USDA, 1981).

The Yale-Myers Forest is located in the Eastern Highlands Region of Connecticut, with a landscape and surficial geology that is defined by Pleistocene glaciation (MacFaden and Ruth, 1972). Elevation at the forest ranges from 170 to 320 m with a rugged topography of broad, flat-topped ridges with many rock outcrops and narrow, often swampy valley bottoms (Meyer and Plusnin, 1945). The dominant soil types are Gloucester fine sandy loam, Brookfield fine sandy loam, Hinckley fine sandy loam, and Charlton. These soils are Typic and Lythic Dystrochrepts of till-derived material over granite-gneiss and schist, with bedrock lying at an average of 1–6 m, and have relatively high potential for forest production (Meyer and Plusnin, 1945; USDA, 1981).

Yale-Myers Forest falls within the Central Hardwoods–Hemlock–White Pine zone as described by Westveld et al. (1956). Dominant tree species include red oak (*Quercus rubra* L.), black oak (*Quercus velutina* Lam.), eastern hemlock (*Tsuga canadensis* (L.) Carriere), black birch (*Betula lenta* L.), sugar maple (*Acer saccharum* Marsh), red maple (*Acer rubrum* L.,), eastern white pine (*Pinus strobes* L.), white ash (*Fraxinus americana* L.) and pignut hickory (*Carya glabra* (Mill.) Sweet). The forest has a relatively rich understory flora composed of many of the shrubs, herbs, and ferns typical of central and northern Connecticut. Mountain laurel (*Kalmia latifolia* L.) is the dominant shrub. Hay-scented fern (*Dennstaedtia punctilobula* (Michx.) T. Moore) and New York fern (*Thelypteris noveboracensis* (L.) Nieuwl. are the dominant ferns. Common upland forest herbs include Canada mayflower (*Maianthemum canadense* Desf.), wild sarsaparilla (*Aralia nudicaulis* L)), star flower (*Trientalis borealis* Raf.), partridgeberry (*Mitchella repens* L.), violets (*Viola spp.*), wintergreen (*Gaultheria procumbens* L.), and sessile-leaf bellwort (*Uvularia sessilifolia* L).

Approximately 70% of Yale-Myers Forest is under active timber management, with the remaining area held as early or late successional reserves, forested wetlands, roads, or other non-timber production classification. Typical for central and southern New England, the majority of the land was cleared for agriculture or grazing between the mid-18th and mid-19th centuries (Smith, 1989; Foster, 1992). After land abandonment at the end of the 19th century, natural reforestation began with old-field white pine stands that later gave way to the current mixed–hardwoods–hemlock forest type. Most current stands originated at the turn of the 20th century, or after the hurricane of 1938 (Smith, 1989). Crown thinning and shelterwood systems are the most common treatments with an emphasis on the promotion of natural advance regeneration.

3. Materials and methods

Plot data was used to analyze floristic patterns at the Yale-Myers Forest. All understory and overstory data was collected between June 28, 2004 and August 14, 2004. All topographic data was collected during the summer of 2003.

Plots used for this study were originally mapped at the Yale-Myers Forest in 1978. Thirty transects were randomly located at the forest, with 10 circular, 4-m radius fixed area (50 m^2) plots systematically spaced at 20 m along each transect. In 1996, 10 additional transects were added following the same methods, for a total of 40 transects containing 400 plots, 386 of which were used for this study. Transects fall within a variety of forest cover types, with the majority being contained in areas zoned as production forest by current land-use designation. The locations of all plots have been recorded using global positioning satellites and are stored in a permanent database with The Yale School Forest records. Data from the original transects have been used for several other studies including seedling regeneration patterns (Kittredge and Ashton, 1990) and deer browse impacts (Kittredge and Ashton, 1995).

At each 50 m^2 fixed plot, data was collected on all vascular understory plants including herbs, ferns and woody vines and shrubs. Plots were divided into four equal quadrants divided by cardinal direction, and each understory species present within a plot was tallied according to the number of quadrants it occurred in, regardless of the number of individuals present. Three common, native species considered to be strong competitors for understory growing space, mountain laurel, hay-scented fern and Pennsylvania sedge (*Carex pensylvanica* Lam.) were recorded by ocular estimation of percent cover of total plot area.

Using the center point of each fixed area plot, point sampling was used to tally overstory basal area for each plot (Avery and Burkhart, 1993). Overstory trees ≥5 cm DBH were tallied by species using a 2.5 BAF metric prism. Occurrences and basal area for all snags ≥10 cm DBH were recorded following the same method.