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Ground-layer plant community responses to even-age and uneven-age silvicultural treatments in Wisconsin northern hardwood forests

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Abstract

We evaluated ground-layer plant diversity and community composition in northern hardwood forests among uncut controls and stands managed with even-age or uneven-age silvicultural systems. Even-age treatments included diameter-limit cuttings (20-cm diameter at 30-cm stem height) in 1952 and shelterwood removals in 1964. Uneven-age treatments included three intensities of selection harvest (light, 20.6 m^2/ha residual basal area after harvest; medium, 17.2 m^2/ha residual basal area; and heavy, 13.8 m^2/ha residual basal area) that were applied in 1952, 1962, 1972, and 1982. All treatments were winter logged over snow pack. In 1991, plant diversity and community composition were examined. Species richness for spring ephemerals ranged from 1 to 6 species/150-m^2, spring ephemeral diversity (Shannon's Index of Diversity) averaged 0.57 ± 0.04 and evenness averaged 0.45 ± 0.03. Summer flowering species richness ranged from 1 to 18 species/1-m^2, with an average diversity of 0.71 ± 0.07 and evenness of 0.42 ± 0.03. We found no significant differences among treatments for any of these variables, although power to detect a difference (at $p = 0.05$) was low in all cases (0.15–0.55) due to high variance and low replication. Community composition was not significantly different among the treatments, for either spring ($p = 0.09$) or summer ($p = 0.79$) flora. Few exotic species were found in any treatment. Lack of exotic invasions and minimal differences in plant diversity or composition among treatments may be due, in part, to the negligible amount of soil disturbance that resulted from winter logging. While other (unmeasured) ecosystem components may differ among these silvicultural treatments, our results suggest that ground-layer plant communities in northern hardwood ecosystems are either resistant to change or have recovered within the 40 years since disturbance in the even-age treatments and within 10 years since disturbance in the uneven-age treatments.

Keywords: Herbaceous plant diversity; Richness; Evenness; Uneven-age management; Even-age management; Northern hardwoods; Winter logging

1. Introduction

Today, the success of silvicultural prescriptions is judged on more than the traditional measures of regeneration responses and growth and yield of commercial tree species. An increasing number of landowners and organizations are managing to sustain a wide variety of ecosystem goods and services. In particular, the sustainability of plant species diversity in the understory is considered an important metric by which to judge the efficacy of silvicultural treatments, because ground flora play a fundamental role in the structure and function of ecosystems (Roberts and Gilliam, 1995) and are sensitive to environmental changes (Pregitzer and Barnes, 1982; Rubio et al., 1999). Designing silvicultural systems that restore or sustain native and late-successional species diversity, while also meeting goals for timber production, is a growing area of research. Silvicultural systems to meet these objectives are being developed and evaluated for a wide variety of forest ecosystems (e.g. Muir et al., 2002; Seymour et al., 2002; Palik and Zasada, 2003; Aubry et al., 2004).

Silvicultural experiments and surveys of stands that have contrasting management histories can be used to better understand the diversity responses to silvicultural treatments on ground-layer plant diversity and community composition. Some studies have found that ground-layer plant communities in stands managed with uneven-age systems differed little from control forests when assessed 10–15 years after the last treatment (Metzger and Schultz, 1984; Jenkins and Parker,

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1999). In contrast, recent work on ground-layer plant communities in northern hardwoods in Wisconsin and Michigan suggests that uneven-age management using a selection system in second-growth stands, shifted the community from species representative of old-growth conditions to weedy and early successional species (Scheller and Mladenoff, 2002).

Comparisons of plant community responses between unmanaged stands and those managed using even-age silvicultural approaches show increases in species diversity in the first few years after harvest (Outcalt and White, 1981; Gilliam et al., 1995; Halpern and Spies, 1995), followed by recovery to conditions similar to uncut forest by 50–60 years (Hix and Barnes, 1984; Albert and Barnes, 1987; Ruben et al., 1999). A similar pattern of recovery time has been shown in understory species composition of northern hardwoods in Michigan. Species composition showed the greatest difference 4–5 years after even-age and uneven-age harvests, but the composition was similar to controls in all treatments after 50 years (Metzger and Schultz, 1984). There are notable exceptions to this recovery pattern. For instance, Appalachian hardwood plant communities that were clearcut 50 years ago had half the species richness of primary old-growth forest in the same area (Duffy and Meier, 1992). In Michigan, understory species composition of northern hardwoods was significantly different among management regimes that included even-age (clearcut 65–82 years ago), uneven-age (selection entry 12–14 years ago), and control (old-growth) (Scheller and Mladenoff, 2002). However, working in central hardwoods in Indiana, Jenkins and Parker (1999) found that, after 7–26 years, stands managed with even-age and uneven-age approaches did not differ in understory species composition.

Ground-layer plants compositional and spatial patterns are highly sensitive to environmental conditions. One study found that herbaceous understory composition was more affected by site resource availability than by clearcutting (Gilliam et al., 1995). In southern Ontario, soil disturbance patterns from harvesting were related to percent herbaceous species lost, while harvesting intensity was not related (Reader, 1987). A different study found that post-harvest spatial pattern of understory vegetation species was highly related to its location prior to harvest (Hughes and Fahey, 1991).

Many studies compare only even-age stands with uncut control stands, omitting uneven-age treatments. Even among studies of even-age systems, often only clearcut systems are evaluated relative to controls (Gilliam et al., 1995; Hix and Barnes, 1984; Albert and Barnes, 1987; Hughes and Fahey, 1991; Duffy and Meier, 1992; Ruben et al., 1999). Studies examining uneven-age stands often report results after only one selection harvest (e.g. Reader, 1987; Jenkins and Parker, 1999), with little understanding of the long-term implications of multiple (two or more) entries. Additionally, there may be no quantitative data describing the nature of the selection system, to allow an interpretation of likely effects on resources and establishment and growth conditions (e.g. Jenkins and Parker, 1999; Scheller and Mladenoff, 2002). Finally, few studies were designed experiments that included randomization of treatments (e.g. Metzger and Schultz, 1981, 1984; Reader, 1987).

Our study provides a unique opportunity to examine the effects of uneven-age and even-age silvicultural treatments on ground-layer plant communities after 40 years of management, in a replicated design. We compared ground-layer plant community data from a long-term study of contrasting northern hardwood silvicultural approaches (even-age and uneven-age management and controls in northern Wisconsin, USA. The experimental design included treatment randomization and replication in blocks, with stands and blocks occurring within one ecosystem or habitat type. At the time of plant community sampling, uneven-age selection treatments had been applied four times over a 40-year period, and even-age approaches had been applied once at the beginning of this period. Our objective was to evaluate how ground-layer plant species richness, diversity, and composition differed among contrasting silvicultural approaches and controls after 40 years of management.

2. Methods

2.1. Study site

In 1952, North Central Research Station (formerly known as the Lake States Forest Experiment Station) of the USDA Forest Service installed a ''cutting methods'' experiment on the Argonne Experimental Forest in northern Wisconsin, USA, in a second-growth, northern hardwood forest that regenerated after clearcutting around 1902. The original intent of the study was to contrast a range of silvicultural treatments (both even-age and uneven-age) for their efficacy at meeting timber production and regeneration objectives. The forest is dominated by sugar maple (*Acer saccharum* Marsh., averaging 63% of overstory basal area), with lesser amounts (4–9% basal area each) of white ash (*Fraxinus americana* L.), yellow birch (*Betula alleghaniensis* Britt), basswood (*Tilia americana* L.), hemlock (*Tsuga canadensis* (L.) Carr), and red maple (*Acer rubrum* L.) (Niese and Strong, 1992). The site supports quality northern hardwood development, with site indices (50 year base) of 19.8 m for sugar maple and yellow birch and 21.3 m for basswood. Soils are predominantly sandy loams of the Argonne-Sarwet series, while the habitat type is largely *Acer/Osmorhiza-Caulophyllum* (Kotar et al., 2002).

2.2. Experimental design

The experiment consisted of a randomized block design with six treatments randomly assigned to 1-ha stands within each of the three blocks. Even-age treatments included diameter-limit cutting and shelterwood. The diameter-limit treatment removed all trees greater than 20-cm diameter at 30-cm stem height in 1952 (39 years before ground-layer plant sampling (see Section 2.3)). Mean ($\pm$ standard error) residual basal area was 5.3 ± 1.7 m^2/ha. The shelterwood treatment was cut to 60% crown cover or about 9.2 m^2/ha in 1957. The shelterwood overstory was removed in 1964 (27 years before sampling).