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Effects of single-tree and group selection harvesting on the diversity and abundance of spring forest herbs in deciduous forests in southwestern Ontario

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Abstract

Selection harvesting, by mimicking natural disturbance regimes of eastern deciduous hardwood forests, has been applied as a sustainable management practice that combines wood production with biodiversity conservation. However, the effects of this technique on understory herbs are unclear, particularly for spring ephemerals which have been suggested as sensitive to disturbance. Here, we experimentally assess the immediate effects of single-tree and group selection harvesting on spring ephemeral richness, diversity and abundance in deciduous forests of southwestern Ontario, Canada. Spring herbs were quantified in 4 m^2 plots before and one growing season after harvesting and compared to similar uncut, reference stands. The percent of species lost was significantly higher in reference than harvested plots. Mean species richness significantly increased after harvesting, predominately due to an increase in spring–summer species. Increases in the diversity of early spring flowering species were significantly greater in the group selection plots than reference plots. At the community level, no species appeared to be vulnerable to harvesting, and ordination analysis indicated that post-harvest communities were primarily determined by pre-harvest community composition. Furthermore, no species declined in abundance in response to harvesting, and overall percent cover increased proportionately more in single-tree selection plots than in group selection or reference plots. While harvesting appears to have negligible effects on spring ephemerals immediately following harvest, we recommend additional studies over longer time frames to assess possible successional effects and to discriminate treatment induced changes from naturally high yearly variation in species composition.

Keywords: Forest herbs; Spring ephemerals; Selection harvesting; Disturbance; Plant community composition; Richness; Diversity

1. Introduction

As forests across North America continue to be fragmented and influenced by human activities, the importance of maintaining biodiversity has become widely recognized (Millar et al., 1990; Burton et al., 1992). This is particularly evident in southwestern Ontario where only 3% forest cover remains in some counties. An estimated 87% of the remnant forest is privately owned and managed according to a variety of landowner objectives, with commercial timber harvesting being a dominant land-use practice (OMNR, 2000). Consequently, determining whether current harvesting practices are sustainable and what silviculture methods best meet landowner objectives while still maintaining a healthy ecosystem is of increasing importance.

In the deciduous forests of eastern North America, woodland herbs account for most of the vascular plant diversity (Whigham, 2004). They play a vital role in ecosystem functioning, particularly in nutrient cycling (MacLean and Wein, 1977; Peterson and Rolfe, 1982; Anderson and Eickmeier, 2000). Of all vegetation strata, the understory is affected most by disturbance and micro-environmental change (McCarthy and Facelli, 1990; Meier et al., 1995). In particular, spring ephemerals or 'vernal' herbs which are visible on the forest floor before overstory canopy closure in late spring (Meier et al., 1995), have been identified as a group of plant species highly vulnerable to disturbance (Duffy and Meier, 1992; Keddy and Drummond, 1996; McLachlan and Bazely, 2001).

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A considerable amount of research has addressed the response of understory herbs to harvesting, particularly in response to clear-cutting (Duffy and Meier, 1992; Gilliam et al., 1995; Halpern and Spies, 1995; Meier et al., 1995; Gilliam, 2002; Roberts and Zhu, 2002; Small and McCarthy, 2002a; Pykala, 2004). Some researchers have found no significant difference in species richness and composition between cut and uncut stands 20+ years post-harvest (Metzger and Schultz, 1984; Gilliam et al., 1995; Gilliam, 2002), while others have found that herb communities are negatively affected by clear-cut logging (Halpern and Spies, 1995; Scherer et al., 2000) and may take >50 years to recover (Duffy and Meier, 1992; Meier et al., 1995). The lack of consistency in findings demonstrates the possible system-specific nature of herb-layer responses (Halpern and Spies, 1995) and the need for further research into the understory dynamics of forest communities (Matlack, 1994; Whigham, 2004).

Selection harvesting has been applied as a sustainable alternative to clear-cut harvesting in forests dominated by shade-tolerant species (Reader, 1987; Fredericksen et al., 1999). By mimicking natural gap-phase dynamics and small-scale disturbance regimes, selection harvesting creates heterogeneous stand structures similar to mature forests (Deal, 2001; Deal and Tappeiner, 2002) and is likely to have fewer negative impacts on forest biodiversity than clear-cut harvesting (Reader and Bricker, 1992b; Meier et al., 1995). In southern Ontario selection harvesting is recommended for most broadleaf forests (OMNR, 2000). Depending on forest composition and objectives, selection harvests can be designed to remove single trees, groups of trees or a combination of the two. In single-tree selection, harvesting to a target residual basal area is achieved by removing individual trees from a range of diameters throughout an entire stand. In contrast, group-selection is used to encourage the regeneration of mid-tolerant species and involves removing trees in patches (up to 50 m in diameter) to create forest gaps.

Selection harvesting differs from natural gap dynamics in several ways, including: the scale and frequency of disturbance; woody debris removal; soil structure from compaction and erosion by logging equipment; and direct surface disturbance such as trampling (Bratton, 1994). All of these differences have the potential to affect understory herbaceous communities in both positive and negative ways (Reader, 1987; Hughes, 1992; Whigham, 2004; Scheller and Mladenoff, 2002; Small and McCarthy, 2002a).

Despite the complexity of responses to changes in their environment, herbs appear to be resilient to the effects of single-tree selection harvesting (Fredericksen et al., 1999; Deal, 2001; Gotmark et al., 2005). Yet, few studies have compared the understory of harvested gaps to the understory of undisturbed canopy (e.g., Metzger and Schultz, 1984; Collins and Pickett, 1987; Jalonen and Vanha-Majamaa, 2001; Schumann et al., 2003) and even fewer have compared single-tree to group selection with regard to spring herb diversity (e.g., Metzger and Schultz, 1984; Jalonen and Vanha-Majamaa, 2001). Given that group selection creates very different light environments than single-tree selection, and that light strongly influences herb layer diversity, the impacts of these two harvesting prescriptions on spring herbs in southern Ontario are likely to differ. Furthermore, Gotmark et al. (2005) found that the herb layer is highly dynamic in the short-term and recognized the need for experiments with strong temporal control (i.e. before-after studies) to measure direct effects.

We compared the impacts of single-tree and group selection harvesting on spring herb communities by evaluating harvesting effects on: (1) loss of species, (2) richness, diversity and evenness, (3) changes in community composition, and (4) frequency and abundance of individual species that are potentially sensitive to disturbance. We hypothesized that most species would respond positively to harvesting and overall richness and diversity would increase in harvested plots. However, those species identified as sensitive to disturbance would decrease or even be locally extirpated by harvesting, and these species-specific responses could alter community composition.

2. Methods

2.1. Study area

The study took place in six woodlots within Norfolk and Middlesex counties, southern Ontario, Canada (~42°42′N, 81°81′W). This area marks the northernmost edge of the Carolinian deciduous forest region and contains a number of species found nowhere else in Canada (Fox and Soper, 1955). Woodlots ranged in size from 97 to 270 ha and were embedded in an intensive agricultural matrix (14–25% forest cover). Dominant canopy species included: red maple (*Acer rubrum* L. 17% basal area (BA)), red oak (*Quercus rubra* L. 13% BA), silver maple (*Acer saccharinum* L. 12% BA), white oak (*Quercus alba* L. 7% BA), freeman maple (*Acer freemanii* A. E. Murray 6% BA), sugar maple (*Acer saccharum* Marsh. 6% BA), and green ash (*Fraxinus pennsylvanica* Fern. 5% BA).

2.2. Woodlot selection and harvesting

Woodlots with similar stand structure (i.e. basal area and canopy closure) and species composition were selected for study. All woodlots had previously been harvested prior to the late 1970s, but had returned to a mature, closed canopy stand structure before the application of our treatments. Two replicates from each of three treatments were studied — 2 woodlots harvested under single-tree selection, 2 woodlots harvested under group selection, and 2 reference woodlots left unharvested (3 treatments × 2 replicates = 6 woodlots). Treatment areas were similar in size (average = 32.9 ± 3.9 ha). Within each group selection woodlot, 5 small (400 m^2) and 4 medium (700 m^2) gaps were intermixed and spread across one half of the treatment area and 3 large (1400 m^2) gaps were spread across the other half of the treatment area. Individual gap locations were chosen based on silviculture principles for regenerating mid-tolerants with the caveat that they be at least 50 m from the edge of the forest (to reduce the possibility of confounding edge effects due to proximity to hard edges) and at