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Review

A meta-analysis of the effect of forest management for timber on understory plant species diversity in temperate forests

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ABSTRACT

Many studies have examined affects of forest management—particularly regeneration treatments—for timber on understory plant diversity. These studies taken independently show no clear trends in diversity with degree and/or periodicity of disturbance from timber harvests. Here we present a meta-analysis synthesizing primary field research on response of understory plant diversity to timber harvesting in temperate forests, particularly in North America. Across a pool of 96 studies, we find no effect on understory plant species richness from managing forests for timber. When intensive regeneration harvests (e.g. clearcut, shelterwood) are separated from less intensive regeneration harvests (e.g. single tree and group selection systems) and thinnings, selection harvests show a positive effect on species richness. Intensive regeneration harvests and thinning treatments had no effect on species richness. We examined the role of stand development following regeneration treatments, and found no detectable effects on species richness for even-aged stands within the first 50 years after clearcut and shelterwood timber harvests. Stands in later successional stages, however, had lower species richness than un-logged stands. All these findings together suggest that silvicultural activities focused toward timber management are not inconsistent with conservation of understory plant diversity. We suggest site-specific characteristics (e.g. resource availability, resource heterogeneity) at various temporal and spatial scales, have a larger role to play in defining understory plant diversity than the disturbance of harvesting itself. Managers therefore should consider underlying factors of site and species composition, and should examine regionally specific studies when planning silvicultural treatments. In addition, it should be noted that our analysis makes no distinction in classifying the nature of diversity, especially between colonizing early-successional species that peak after 1–10 years and then disappear, and late successional, often more site specific and shade tolerant species, that may persist post harvest but often disappear or retract in their range and abundance. Further studies are needed to tease out differences in diversity in relation to successional stage and affects of forest management.

Contents

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1. Introduction

Forests account for roughly a third of global land cover, and are home to much of the planet's biodiversity (FAO, 2010; UNEP, 2010). Biologically diverse systems, they also serve a variety of human needs. Of these needs, timber and pulp are of critical importance, and the effects of their extraction are the focus of a large body of research. While often overlooked, much of the biodiversity in forests as well as many non-timber forest products and other ecosystem services are provided by understory plants (Whigham, 2004). Although these species are not specifically targeted in timber extraction, harvest activities are known to affect understory plant communities (Roberts and Gilliam, 2003). The degree to which harvest intensity, site, and successional process interact to drive these changes is less certain.

Many researchers have investigated the effects of even-aged harvesting on understory plant diversity with mixed results. A review by Roberts and Gilliam (2003) examining clearcut harvesting in eastern North America found no clear pattern predicting understory plant diversity response. Moola and Vasseur (2008) conducted a similar review, but focused on late-successional forests types of northeast North America, they found only small effects of clearcutting on understory plant species richness. Observed increases in understory plant diversity soon after (<20 years) clearcut harvesting may be a result of early successional colonizers (Jenkins and Parker, 1999; Battles et al., 2001; Brosofske et al., 2001; Moola and Vasseur, 2004; Kreyling et al., 2008; Loya and Jules, 2008). Although this spike in richness is not always observed (Meier et al., 1995; Nagaike et al., 1999; Scherer et al., 2000). There is evidence that understory residual plant diversity generally declines after clearcutting of late successional forests (Moola and Vasseur, 2008). Studies examining thinning treatments also show inconsistent effects on understory plant species richness. Some show positive effects on diversity (Thomas et al., 1999; Metlen and Fiedler, 2006), others negative (Wyatt and Silman, 2010), and some no effect (Wayman and North, 2007; Schwilk et al., 2009). Uneven-aged harvesting through selection regeneration methods has also failed to show clear trends. Falk et al. (2008) found increased understory plant species richness in both single-tree and group selection treatments, while Jenkins and Parker (1999) found increases in group-selection, but decreases in single-tree treatments. Other studies have found single-tree selection to have either positive effects (Scheller and Mladenoff, 2002) or no effect (Kern et al., 2006). Many of these results may depend on what groups of plants were being investigated (residual, colonizing, total), the condition and successional age of the forest, and the forest type examined. Successional stage is an important consideration, particularly following even-aged silvicultural regeneration methods (clearcut, seed tree, shelterwood) (Smith et al., 1997). The structure and amount of competition and resources available on the forest floor changes more dramatically, and phases of development move through time more uniformly (initiation, stem exclusion, understory reinitiation, old growth) as compared to uneven-aged methods (Oliver and Larson, 1996). Therefore understory plant diversity is expected to be more temporally dynamic in even-aged regeneration methods.

In summary, there has been a considerable amount of research focused on the response of understory plant diversity following forest management, but there has not been a systematic analysis of all these studies taken together. Of particular importance is the role of harvest treatment intensity in mediating effects on understory plants. Harvesting treatments vary greatly depending on whether the goal is to promote regeneration (clear cut, seed tree, shelterwood), promote growth of the existing stand (thinning) or a combination (selection). Past studies have focused on specific forest types, specific regions, or particular forest conditions (i.e. old growth). Through meta-analysis we seek to identify patterns over the complete temperate forest biome, including both coniferous and broadleaved forests. In this paper we integrate current research to answer the following questions. Firstly, does forest management through timber harvesting have a negative effect on understory plant diversity in temperate forest systems? Secondly, does the type of silvicultural treatment (i) even-aged regeneration methods (clear cutting/shelterwoods), (ii) thinning, (iii) uneven aged regeneration methods (selection) define those effects? Lastly, are successional patterns of understory plant species diversity apparent following even-aged methods of regeneration?

2. Methods

2.1. Data selection

We performed a meta-analysis examining understory plant species diversity and timber harvesting in temperate forests, particularly focused in North America. We chose to analyze species richness because it is both the simplest and the most commonly reported diversity measure (Magurran, 2004). Also in many circumstances it can be easily extrapolated from datasets on understory plant communities, even when not directly reported, allowing us to include more data.

We performed an intensive literature search through three databases (Google Scholar, Scirus, and ISI Web of Science) with the keywords: forest, understory, diversity, and logging – and then completed additional searches first substituting harvesting for logging, and then richness for diversity. When necessary, values were extracted from figures using the program Data Thief (Tummers, 2006). In circumstances where richness data was collected, but not reported, or where no measure of variance or sample size was disclosed every effort was made to acquire those data by contacting primary authors. In experimental designs that tested more than one variable (e.g. thinning and burning) only the control and the silvicultural harvesting treatment were analyzed. Comparative studies that looked at more than one silvicultural treatment (e.g. clearcut vs. thinning) were analyzed separately, as were studies that examined more than one group of plants. We included control-treatment comparisons, and allowed studies utilizing observational chronosequences, but excluded diachronic studies that lacked a true control (i.e. before-after comparisons only). Control conditions for comparisons included both "old growth" and "mature" stands as defined by individual researchers. These controls encompassed a diverse range of land-use and disturbance histories (see Supplementary materials). In studies that reported repeated measures only final values were used. We insured that results were only used once when reported in more than one paper. We included studies that examined understory response,