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Responses of community structure, diversity, and abundance of understory plants and insect assemblages to thinning in plantations

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ABSTRACT

Identifying effective management operations for plantations is important for conservation of biodiversity in a plantation-dominated landscape. We tested whether pre-commercial thinning influenced community structures and could be an effective strategy for increasing diversity and abundance of plants and animals in plantations. We designated thinned and unthinned study stands in Japanese cedar (*Cryptomeria japonica*) plantations and compared the communities of understory vegetation, bees, butterflies, hoverflies, and longhorn beetles 1 and 3 years after thinning. The analyses of vegetation showed that pre-commercial thinning affected community structure, but species richness and vegetation abundance were not significantly affected. Thinning affected insect community structure, and both species richness and abundance of all insect groups increased 1 year after thinning. However, 3 years after thinning, significant differences only remained in the species richness of bees and the abundance of bees, butterflies, and hoverflies. These results suggest that pre-commercial thinning in plantation stands influences the community structure of understory vegetation and can be an effective way to increase the diversity and abundance of some insect groups in the short term. However, the results also suggest that the duration of the operational effects of pre-commercial thinning varies among insect groups; thus, the variable effects of pre-commercial thinning should be carefully considered in the conservation-based management of plantation stands.

1. Introduction

1.1. Plantations and biodiversity

Plantations encompass a major proportion of forest area in several countries around the world (FAO, 2007). For instance, 12% of land cover in the UK consists of forest, and 68% of the forest is plantation. Japan also has a high percentage of plantation-dominated landscapes; 68% of its land is covered by forest, and 42% of the forest is plantation (FAO, 2007). Such intensive silvicultural management, in addition to the simplified structure and composition of plantation forests, has negative influences on biodiversity as shown by a study in tropical forests (Barlow et al., 2007), although plantation forests may still contribute to conservation of biodiversity through various means (Lindenmayer and Hobbs, 2004; Brockerhoff et al., 2008).

Nonetheless, more of the world's commercial timber is produced by plantations than by natural and semi-natural forests (Sedjo and Botkin, 1997), and the apparent increasing demands for timber are principally met by growing more timber on plantations (Hartley, 2002). For example, the cover of tropical plantations has increased, although tropical forest cover is declining (Lugo, 1997). Therefore, conservation of biodiversity is becoming a major issue, and identifying effective management operations for plantations is important for the conservation of biodiversity in a plantation-dominated landscape (Kerr, 1999; Cummings and Reid, 2008; Yamaura et al., 2008).

1.2. Effects of thinning on biodiversity

Pre-commercial thinning is a management operation applied in the tending of planted trees for timber production, but might also be performed to promote the biodiversity of plantation forests (Hartley, 2002; Igarashi and Kiyono, 2008). One review indicated that density management by thinning of planted trees could result in changes in both overstory and understory vegetation (Wilson

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and Puettmann, 2007). On the other hand, a study of conifer plantations predicted that thinning is a short-term strategy that is less likely to be effective in promoting species diversity of understory vegetation (Ito et al., 2006). Another study of spruce plantations showed that thinning negatively influenced plant species diversity (Nagai and Yoshida, 2006). However, a previous study conducted for 8 years after thinning of Douglas fir (*Pseudotsuga menziesii*) and western hemlock (*Tsuga heterophylla*) plantations showed that the effects of thinning on understory vegetation communities lasted longer than 3 years (Chan et al., 2006). Thus, the effects of thinning may vary with time after thinning, as well as location and tree species (Thomas et al., 1999).

Understanding the temporal effects of thinning in plantations on the community structure, diversity, and abundance of arthropods is also important, but less studied. Arthropods including insects are used for conservation planning because they occupy a great variety of functional niches and microhabitats across a wide array of spatial and temporal scales (Kremen et al., 1993). The same operations affect arthropods differently from plants (Taki and Kevan, 2007), and arthropods would be sensitive to management operations such as thinning and can act as indicators in plantations (Maleque et al., 2009). Indeed, studies comparing thinned and unthinned forest stands at a single time since thinning have shown positive effects on the diversity and/or abundance of longhorn beetle species (Ohsawa, 2004), Coleoptera (Maleque et al., 2007a) and Hymenoptera (Maleque et al., 2007b).

1.3. Purpose and hypotheses of research

The primary goal of our study was to investigate the effects of tree thinning on the community structure, diversity, and abundance of plants and insects in plantation forests at two times since thinning. We observed understory vegetation and four insect assemblages: bees, butterflies, hoverflies, and longhorn beetles, at high taxonomic resolution. We hypothesized that pre-commercial thinning in plantations would influence the community structure of understory plants and the insect assemblages and could contribute to increasing plant and insect diversity and abundance. However, we also hypothesized that the trends in diversity and abundance would change over time. To test these predictions we selected forest stands with thinning and non-thinning treatments, and then surveyed understory vegetation and insects 1 and 3 years after thinning.

2. Materials and methods

2.1. Study sites

Our study was conducted in Hitachiota, Ibaraki, central Japan (approximately 36°50′N, 140°34′E; 700–800 m above sea level). Although the original dominant canopy trees in the area were deciduous broad-leaved trees such as konara oak (*Quercus serrata*), mizunara oak (*Quercus crispula*), and Japanese beech (*Fagus crenata*), the area covered by conifer plantations greatly increased in this region following the Second World War (Miyamoto and Sano, 2008). The species of conifers planted were mainly Japanese cedar (*Cryptomeria japonica*) and Japanese cypress (*Chamaecypress obtusa*), and plantations now account for more than 90% of the total forested area in the region (Makino et al., 2007).

We selected six unthinned and five thinned forest stands in the study region (Table 1). All five of the thinned forest stands were designated for pre-commercial thinning in 2004 by the Ibaraki District Forest Office, Forestry Agency, for the purpose of tending the remaining trees, and the cut trees were left in the plantation stands. The thinning intensity rate was set to 30% based on timber volume and 50% based on tree number. The dominant plantation species in all of the selected forest stands was *C. japonica*. The mean age and area of selected stands in 2004 was 25 years old and 4.51 ha, respectively (Table 1).

The selected unthinned and thinned forest stands had most likely been thinned at least once before our study was conducted, when the plantation trees were still young. The Forest Office usually only keeps records on such forest management operations for a few years; thus, we could not obtain complete records of all the operations on all forest stands since the plantation trees were planted. However, according to existing operational records, none of the selected stands had been thinned for at least 5 years, and presumably for at least 10 years based on personal communications and our field observations in the year in which the thinning treatment was carried out for our thinned forest stands.

2.2. Survey of understory vegetation

We investigated the effects of pre-commercial thinning on understory vegetation cover and species. In each of the selected forest stands, we established a 10 m × 100 m belt-shaped study plot at the center of the forest stand wherever possible to exclude the effects of neighboring stands of different management types. To minimize the influence of variations in site conditions, we selected stands located on gentle slopes, and the belt-shaped plots were designed to encompass the topographic variation in each stand (Nagaike et al., 2003, 2006). We divided each study plot into 5 m × 5 m quadrats, and we positioned a 1 m × 1 m subquadrat at the corner of each quadrat. We investigated 40 subquadrats in each of the forest stands, but in one forest stand we investigated 30 subquadrats to exclude the effects of neighboring stands. We recorded total understory vegetation cover (percentage) and species of plants <2 m in height within each subquadrat using the Braun-Blanquet method in 2005 and 2007. Varieties of a

Table 1
Cryptomeria japonica plantation stands used for our study in Hitachiota, Ibaraki, central Japan. The stand density of UT6 was not measured.

ID	Treatment	Age	Area (ha)	Stand density (stems/ha)	Year of census	
					Vegetation	Insect
T1	Thinning	26	1.91	2557	2005 & 2007	2005 & 2007
T2	Thinning	27	1.96	1550	2005 & 2007	2005 & 2007
T3	Thinning	27	4.49	1660	2005 & 2007	2005 & 2007
T4	Thinning	27	2.50	1660	2005 & 2007	2005 & 2007
T5	Thinning	26	2.32	1260	2005 & 2007	2005 & 2007
UT1	Unthinning	21	4.88	3250	2005 & 2007	2005 & 2007
UT2	Unthinning	26	3.92	2810	2005 & 2007	2005 & 2007
UT3	Unthinning	25	3.45	2590	2005 & 2007	2005 & 2007
UT4	Unthinning	23	4.81	2470	2005 & 2007	2005 & 2007
UT5	Unthinning	30	14.29	2490	2005	2005
UT6	Unthinning	19	5.08	N/A	–	2007
Mean		25.18	4.51			