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Effectiveness of local conservation management is affected by landscape properties: Species richness and composition of saproxylic beetles in boreal forest clearcuts

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ABSTRACT

Landscape context is known to affect species diversity patterns and can even influence the effectiveness of local conservation management in agricultural landscapes. For other land uses, like forestry, landscape effects are poorly known. We aimed to determine whether landscape composition modifies the response of saproxylic beetle species to local habitat and conservation management, with focus on dead wood and prescribed fire, in managed boreal forest landscapes. We surveyed beetles on 32 clearcuts in central Sweden. We measured local (fire, dead wood, flower resources, patch size) and landscape factors (fire, dead wood within 1–2 km radius), and analysed interactions between these in mixed models. The response was species richness of beetles with different habitat specialization – conifer specialists, deciduous specialists, flower visitor and pyrophilous species, and abundance of a red-listed species, *Tragosoma depsarium*. Local and landscape factors, as well as interactions between them, affected species richness patterns. Prescribed fire and amount of dead wood, both on local and landscape scale, affected species richness and composition of several groups. There were interactions between local and landscape factors in five models out of six. Locally, we observed a positive response to flower richness for several groups, while the response to prescribed fire and dead wood amounts typically was affected by landscape factors. The results suggest that effectiveness of local conservation management is affected by landscape properties; the positive effects of local dead wood amounts and burning occurred on clearcuts in landscapes with large amounts of dead wood, but not in landscapes with small amounts of dead wood.

1. Introduction

Understanding landscape effects on local diversity patterns and ecological processes is fundamental for developing successful approaches for biodiversity conservation (Tscharntke et al., 2012). One reason for this is that landscape composition can influence the effectiveness of local conservation management (Tscharntke et al., 2005; Batáry et al., 2011). Habitat improvement actions (e.g., agri-environment schemes, AES) appear to be most effective in simple landscapes (with 1–20% non-crop habitats) (Rundlöf and Smith, 2006; Rundlöf et al., 2008; Batáry et al., 2010; Concepción et al., 2012; Smith et al., 2010). This is because in more complex landscapes (>20% non-crop habitats), organisms move between habitats and therefore biodiversity is high everywhere, while in cleared landscapes (<1% non-crop habitats) the species pool is so small that the local species richness does not respond to conservation management. So far, landscape effects on local conservation effectiveness have been studied in agricultural systems, but rarely in other managed habitats, such as forests.

Wide regions of boreal Europe and North America are dominated by managed forest land harvested by clearcutting. In such forests, conservation actions to mitigate negative effects of clearcutting are often applied in form of green tree and dead wood retention (Franklin et al., 1997; Gustafsson et al., 2012). Prescribed fire is also used in some regions, commonly in Fennoscandia, to promote species that suffer from loss of natural disturbance dynamics due to fire-suppression (Granström, 2001; Vanha-Majamaa et al., 2007). Local effects of these actions have been studied on many taxa (tree retention: Rosenvald and Lõhmus, 2008; Gustafsson et al., 2010; fire: Martikainen et al., 2006; Toivanen and Kotiaho, 2007), while the importance of landscape composition for the effectiveness of living-tree and dead wood retention, and prescribed fire, in promoting species diversity is largely unknown. However, it has been suggested that the species richness

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of fire-dependent insects after habitat restoration depends on the regional context, with more species colonising burned forests where the management history is shorter (Kouki et al., 2012).

A large proportion of forest species are saproxylic, i.e. dead wood dependent (for instance, about 25% in Finland; Siitonen, 2001), and many of them are today declining or threatened (Stokland et al., 2013). This is because dead wood amount and diversity decreases when forests are managed (Siitonen, 2001; Similä et al., 2003). Saproxylic beetles are dependent on dead wood for their larval development. Other requirements on the habitat are less known, but some species visit flowers to feed on pollen and nectar as adults (Palm, 1959). Beetles are known to respond to flower density or species richness in grassland (Hegland and Boeke, 2006) and deciduous forest habitats (Cerambycidae, Fayt et al., 2006; Müller et al., 2008). However, to what extent flowers constitute a limiting factor for saproxylic beetles in boreal forests is not known. Forest fires create large amounts of dead and dying trees, which benefit many saproxylic organisms. There are also certain species that are specifically associated with burned habitats (Boucher et al., 2012; Toivanen and Kotiaho, 2007). Despite well studied local effects, few studies have addressed the importance of surrounding landscape for saproxylic diversity (Sverdrup-Thygeson et al., 2014). Thus, the knowledge is still limited on the relationship between saproxylic species diversity and distribution of dead wood on different spatial scales, recent fire history in the landscape, and interactions between local and landscape effects.

We studied saproxylic beetles on clearcuts in managed boreal forests and assessed effects of local management and landscape context on the species richness and species composition of all saproxylic beetles and within ecological groups connected to specific resources: (i) coniferous wood specialists, (ii) deciduous wood specialists, (iii) pyrophilous species, and (iv) flower visitors. Moreover, we analysed abundance of the most frequently occurring red-listed species. For species richness, interactions between local and landscape factors were tested in order to assess the importance of landscape context for local conservation management. We posed the following question: is species richness and composition affected by local habitat characteristics and landscape composition and if so, are the local effects different depending on the landscape context? We expected that species richness would respond positively to high dead wood amount and to resources associated with their habitat specialisation locally. We also hypothesized that resources on landscape scale would be prerequisite for a positive local response to dead wood amount and burning.

2. Methods

2.1. Site selection

The study was carried out in a boreal forest region in south-central Sweden, approximately 22,500 km^2, dominated by managed forests with even-aged stands of Scots pine *Pinus sylvestris* and Norway spruce *Picea abies*. Green tree retention is applied (according to the certification standards at least 10 live trees per hectare) and dead wood is created during harvesting as artificial snags, felled logs, tree-tops and branches. The average amount of dead wood in managed forests in Sweden is about 6 m^3 ha^{-1} (Fridman and Walheim, 2000).

We initially located all burned clearcuts in the region, using data from the Swedish Forest Agency and the two main forest companies in the region, Bergvik Skog and Sveaskog. Based on locations of burned clearcuts, we selected eight landscapes (approximately 10 × 10 km) within the region, with at least 20 km distance between them (Fig. 1). Within each landscape, we selected 3–5 clearcuts separated by at least 500 m; in total 32 clearcuts were surveyed in the region. Where possible, two clearcuts with prescribed fire and two without were selected per landscape, but if only one burned clearcut was available, an additional burned clearcut was added in another landscape in order to balance the number of both types on the regional level. Some of the burned sites were salvage-logged after wildfires and some were clearcut first and then subjected to prescribed burning.

The selected clearcuts had been cut/burned 3–5 years ago. This age interval was chosen because of higher probability to collect species that actually reproduce on the sites, as studies on more recently disturbed sites may predominantly collect individuals

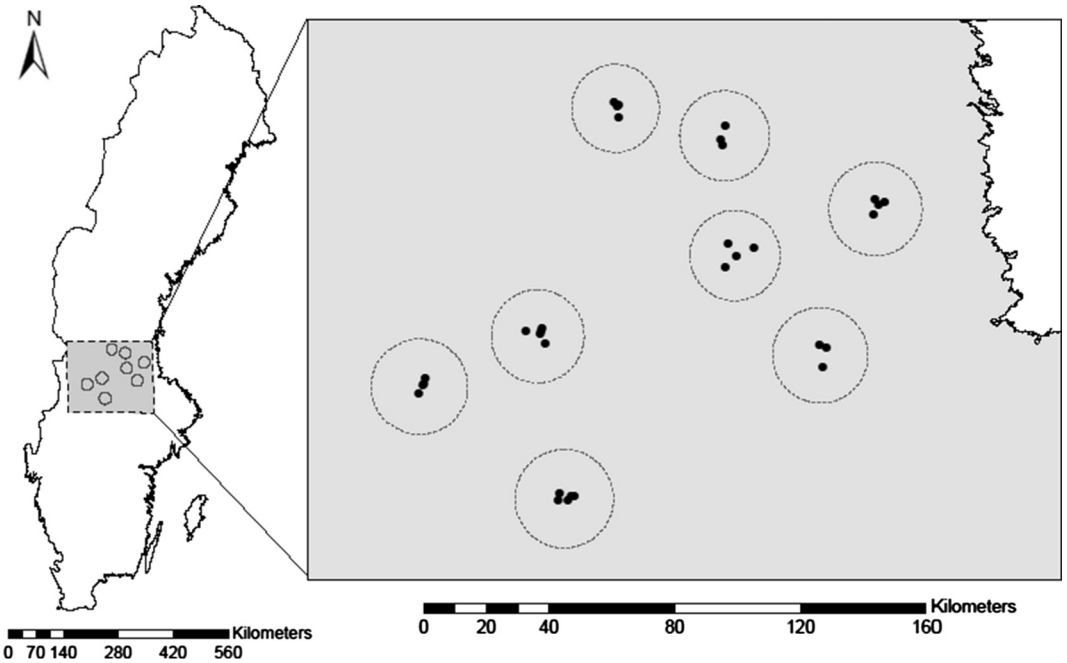

Fig. 1. Map of the study region in central Sweden; locations of the eight landscapes are marked with open circles and the 32 individual sites are marked with filled black circles.