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Oaks retained in production spruce forests help maintain saproxylic beetle diversity in southern Scandinavian landscapes

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ABSTRACT

In Northern Europe, human activities have caused a substantial decrease in the number of old deciduous trees over the last two centuries, leading to a decline in species populations associated with this habitat. One way to mitigate this trend is to increase the abundance of mature and old deciduous trees in commercial forests, such as by tree retention at final harvest. We analysed the biodiversity value of retained mature oaks in the production forests of Norway spruce in southern Sweden, using oaks in pastures as reference. The forest oaks were grown in two different levels of shade. We analysed two categories of saproxylic (i.e. dead wood-dependent) beetles: those utilizing oaks (Group I) and those utilizing oak but not spruce (Group II, which was, therefore, a subcategory of Group I). We found that forest oaks sustained high beetle diversity, in particular, Group I beetles, which were significantly more abundant in forest oaks in heavily thinned patches, as compared with pasture oaks and oaks in moderately thinned patches. For both beetle groups, the composition differed between the forest oaks and pasture oaks, indicating that the forest oaks can be a complementary habitat to that of pasture oaks. There was a positive relationship between oak dead branch diameter and beetle biodiversity, but only for older oaks (~200 years old). We conclude that retaining oaks in production spruce forests can increase the diversity of oak-associated beetles at the landscape scale. Since many oak associated species depend on relatively high levels of insolation, management of retained oaks in production forests should include periodic removal of encroaching trees.

1. Introduction

In Northern Europe, land use practices have led to a substantial decrease of old deciduous trees since the second half of the 1800s (Östlund and Linderson, 1995; Eliasson and Nilsson, 2002). This trend has resulted in habitat loss and population decline for many insects, birds, and lichens associated with old trees. Species that are dispersal limited have been shown to be particularly vulnerable (Siitonen and Ranius, 2015), despite the recent finding of a rather common long-distance dispersal among deadwood-dependent organisms (Komonen and Müller, 2018). Ecologically important habitats in reserves often represent small islands in a landscape that is heavily dominated by production coniferous forests (Lindenmayer and Franklin, 2002; Bengtsson et al., 2003), and may not fully mitigate the loss of habitats. Conservation measures should, therefore, also include areas within commercial forests to increase the habitat amount and connectivity for species that are dependent on old deciduous trees.

Green tree retention, i.e. leaving trees in production forests at final felling, has become a standard management practice in many boreal and temperate regions (Gustafsson et al., 2012). Green tree retention aims to maintain important structural features, such as large and old trees, and to prevent population isolation by connecting habitat patches (Burkey, 1989, Franklin et al., 1997, Kouki et al., 2001). The positive effects of green tree retention on biodiversity have been shown for epiphytic bryophytes and lichens (Hazell and Gustafsson, 1999), vascular plants (Halpern et al., 2005, Nelson and Halpern, 2005), mammals (Moses and Boutin, 2001, Sullivan et al., 2005), and birds (Merrill et al., 1998, Rodewald and Yahner, 2000, Schieck et al., 2000). Green tree retention has also been shown to benefit insect species, in particular saproxylic beetles, which are beetles that are associated with dead wood (Hyvärinen et al., 2006, Rosenvald and Lõhmus, 2008, Sahlin and Ranius, 2009). This group constitutes a considerable part of the species diversity in temperate and boreal forests (Grove, 2002).

In Northern Europe, oaks (*Quercus robur* and *Q. petraea*) host a high

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amount of insect species (Siitonen and Ranius, 2015). In traditionally managed agricultural landscapes, oaks sustain a large number of saproxylic beetles (Ranius and Jansson, 2000), and are, therefore, if present, often retained in production forests. There are, however, concerns that these commonly dense plantations may be too dark for saproxylic beetles. Since oak is a light demanding species, the same could be expected of the beetle fauna of these trees. This could make oaks in spruce production forests less attractive for beetles associated to oak. The number of beetle species on oaks has been shown to be positively correlated with light levels (Koch Widerberg et al., 2012), sun exposure (Sverdrup-Thygeson and Ims, 2002; Bouget et al., 2014) and temperature (Müller et al., 2015). These patterns suggest that increasing light levels may improve oak capacity to host beetle diversity.

The main aim of the current study was to explore the contribution to biodiversity of retained oaks in Norway spruce (*Picea abies*) plantations in relation to oaks growing in pastures, the latter which is known to host a species rich and specialized beetle fauna (Ranius and Jansson, 2000). We studied trees in mid-age plantations, in contrast to earlier studies on biodiversity associated with green tree retention, which have been done on retained trees relatively soon (≤20 years) after clear-cutting (Gustafsson et al., 2010). We tested two hypotheses:

(I) Pasture and forest oaks host different communities of saproxylic beetles and exhibit different diversity levels of beetle fauna, and
(II) Oak properties, such as tree size, age and the amount of dead wood in the crown, affect the diversity of species associated with oaks.

Along with the testing of these hypotheses, the study provides advice for forest owners and policymakers regarding the justification of tree retention and the management of retained trees in production forests.

2. Materials and methods

2.1. Study area and the sites

We studied oaks in eight locations (Fig. 1A, Table 1) in the hemiboreal vegetation zone of Sweden (Ahti et al., 1968). The mean temperature in the study region ranges between −4 °C and 0 °C in January and between 15 °C and 16 °C in July. There is a large variability in the precipitation between the western part (up to 1200 mm/year) and the eastern part (approximately 500 mm/year) of the study area.

Forests cover 63% of the land area in southern Sweden (Götaland). Commercial forestry dominates in the region, with just approximately 2% of productive forest land (forest area with the annual growth > 1 $m^3 ha^{-1}$) being formally protected (Table 1.5 in Nilsson and Cory, 2016). Norway spruce is the most common tree species, comprising 47% of the total volume (SFA, 2017). Norway spruce dominated forests are generally managed using rotationally clear cut even-aged stands which are pre-commercially and commercially thinned two to three times during a rotation period, which can vary between 45 and 70 years. All locations in this study, except for the Tönnersjö, were situated in a region with a high number of beetle species associated with old oaks (Niklasson and Nilsson, 2005). In the 1800s, oaks were common in the study region (Lindbladh and Foster, 2010). However, today oak represents only around 3% of the total timber volume in Southern Sweden.

The studied forest stands have been pastures until the middle of the 20th century. Each stand contained a number of retained mature oaks shaded to a varying degree by the surrounding spruce trees. The latter represented at least 90% of the total stand basal area. The age of the spruce stands ranged from about 40 to 70 years, and was on average about 50 years (Table 1). On six of the eight stands, the spruces were planted, and on two sites they were naturally regenerated following the abandonment of the pastures (sites Strömsrum and Tönnersjö, Fig. 1A). All stands had been subjected to pre-commercial and all but two – to commercial thinning.

We sampled six mature oaks from each location, with four oaks located in the spruce stand and two oaks in nearby pastures. Within each location, we selected oaks to be as similar as possible (except for light levels, see below) in respect to DBH (diameter at breast height), height, tree vitality, and the amount of dead wood in the tree crown. To reduce the correlation in species composition among oaks growing close to each other, we selected only trees with crowns that were isolated by at least three rows of spruce, which corresponded to about 30 m. Most of the forest oaks, however, were located at least 50 m from each other. The pasture oaks were in open conditions, with no or only little shade from neighbouring trees. The distance between the spruce stands and the pasture oaks did not exceed 500–700 m and, in some cases, the pasture and forest oaks were part of the same pasture prior to the spruce establishment.

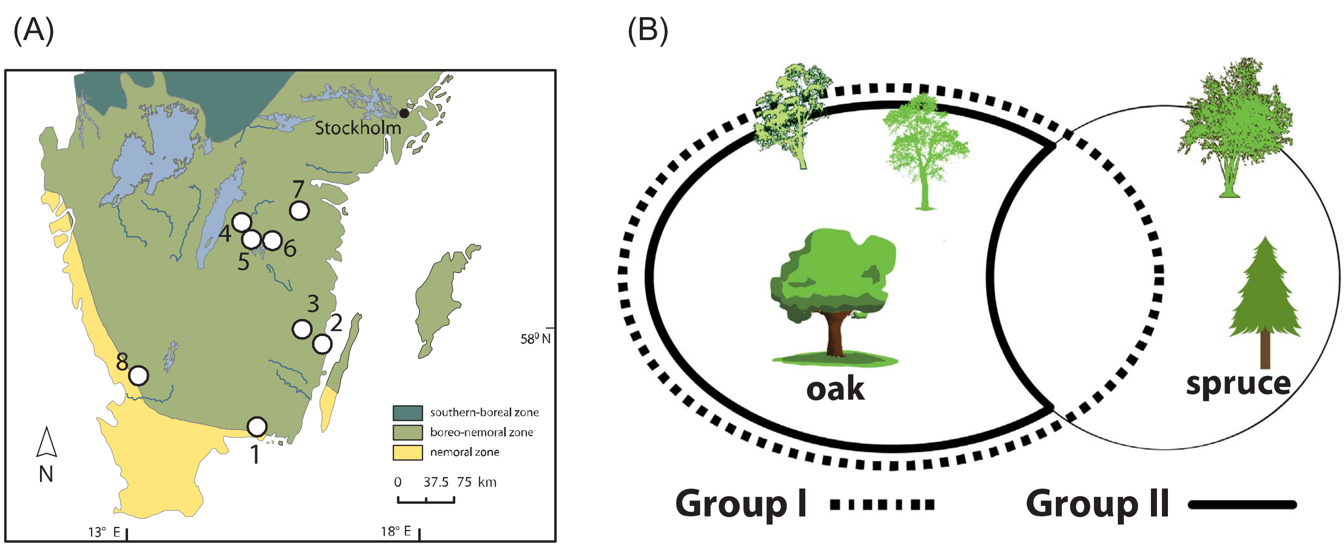

Fig. 1. Location of the eight study sites (A) and definition of beetle groups (B). Numerical location IDs correspond to those in Table 1. Group I represents all species associated with oak, and Group II represents all species associated to oak, except those also associated with spruce. By symbolically showing other trees on Figure B we indicate that both oak- and spruce-associated beetles may have used other tree species, which are present in Southern Sweden (but was largely absent in the studied landscapes).