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Spatial pattern of occurrence of epiphytic lichens on oaks in a heterogeneous landscape

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A B S T R A C T

Quercus robur (oaks) provides an important substrate for many epiphytic lichens, and with increasing age the bark becomes suitable for some rare species. These species may respond to environmental and landscape factors differently, and at different spatial scales. We tested the effect of factors related to the individual tree and the surrounding landscape on the occurrence and richness patterns of lichens species. The study system consisted of 213 oaks selected in a grid system within a 400 km^2 heterogeneous oak-rich area in south-eastern Sweden. Oaks had been selected to be relatively uniform in size (circumference 3.1–4.1 m), and as uniformly distributed as possible in the study area. Landscape factors were calculated for various spatial scales (circles with radius ranging from 28 to 1225 m from a studied oak). One of the landscape factors stands out as of general importance – oak density in the surrounding – while the others (amount of forest, water, houses and arable field) had no effects, or weak effects on only some species. Among the tree specific variables, circumference was consistently important (despite ranging from only 3.1–4.1 m) while inconsistent effects were seen by sun exposure of oak trunk (*Chaenotheca phaeocephala, Ramalina baltica*) and density of shrubs and trees near the tree (*Ch. phaeocephala*). The occurrence patterns of *Cliostomum corrugatum, Ch. phaeocephala, R. baltica* and richness (number of eleven target lichens) were best explained by the density of oaks within radii of 401, 199, 199 and 303 m, respectively. In conclusion, our study highlighted the importance of spatial scale for understanding the occurrence of epiphytic lichens and suggests spatial scales and oak densities that could be targeted for landscape and conservation planning.

1. Introduction

Old growth trees are of particular interest for conservation, since they are an important substrate for a number of organisms from several taxonomic groups, e.g., epiphytic lichens and bryophytes and many insects (Ek and Johannesson, 2005; Jansson et al., 2009; Lindenmayer et al., 2012). Trunks of old growth oaks (*Quercus robur*) host a diverse lichen flora and with increasing age the bark of oaks becomes suitable for rare and threatened species (Johansson et al., 2009; Paltto et al., 2010; Thor et al., 2010; Jönsson et al., 2011). The decline of old oaks in the landscape may be the main reason why many epiphytic lichens only seem to exist in remnant populations in patches with high density of old oaks (Johansson et al., 2009, 2012; Scheidegger and Werth, 2009), and why many oak lichen species are threatened and red-listed (Paltto et al., 2010; Ranius et al., 2008). Most often a reduction of habitat involves increasing isolation of habitat patches, and that may add to the expected decline in species richness (Ranius et al., 2008; Steffan-Dewenter et al., 2002; Löbel et al., 2006).

Conservation of rare and threatened epiphytic lichens need to estimate the densities of old oaks that are needed for continued survival. It is further important to know at what spatial scales to consider such densities. Furthermore, other landscape variables – in addition to substrate availability – may affect lichen species distribution, e.g. forest openness and landscape composition (Jüriado et al., 2003; Bolliger et al., 2007). One way to approach these problems is to explore current species occupancy patterns in relation to potential substrates in small to large scales (Paltto et al., 2006, 2010; Snäll et al., 2003; Holland et al., 2004; Bergman et al., 2012; Musa et al., 2013), which could add to our understanding of the dynamics of species and build better strategies for preservation (Löbel et al., 2006; Sillett et al., 2000; Lättman et al., 2009, 2014).

In a recent study, Paltto et al. (2010). showed that species

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richness and the occurrence of three of five red-listed epiphytic lichen species on oaks were best explained by increasing density of oaks within 0.5 km in a large region (10,000 km^2). However, this study tested scales in fixed steps from 0.5 km and upwards (1, 2, 3, 4 km etc.). Considering these results it would therefore be valuable to explore the spatial scales around 500 m in more detail. For conservation, it is also important to know how to manage the immediate surroundings of valuable oak trees as, for instance, sun exposure of the oak and density of surrounding shrubs and trees can affect the probability of occurrence of lichens (Johansson et al., 2009, 2012; Jüriado et al., 2003; Paltto et al., 2011).

The aim of this study was to investigate the spatial distribution of eleven epiphytic lichens species preferring large and old oaks in a heterogeneous landscape, and to identify the spatial scales, in the range of 28–1225 m, at which species occurrence is best explained. Landscape variables included density of other large oaks in the surrounding of a target tree, as well as potentially important land use types (the amount of houses, and water, agricultural and forested land (Styers et al., 2010; Svoboda et al., 2010)). Furthermore, two tree-specific factors that could be affected by management (sun exposure, and density of nearby trees and shrubs) were also considered. The study was conducted in one of the few remaining landscapes in Northern Europe with a high density of old oaks: the province of Östergötland, south-eastern Sweden (Antonsson and Wadstein, 1991).

2. Materials and methods

2.1. Study species

The eleven lichen species targeted are known to be strongly associated with large oaks, but differing in frequency and abundance (Table 1). For most of these lichens, it has been confirmed that they are very rare outside old oaks (Ranius et al., 2008). All species except *Chrysothrix candelaris* are listed on the Swedish Red List or used as signal species in the woodland key habitat survey in Sweden indicating forests of high conservation value (Table 1 (Gärdenfors, 2010; Johansson et al., 2010)). These species have also been used as indicators of ecological continuity of old oaks in other studies (ESRI, 2011). However, *Chrysothrix candelaris* is relatively common, and widely distributed also on younger oaks.

2.2. Study area and landscape data

The study area is located in the province of Östergötland, south-eastern Sweden. This area has one of the largest abundances of large oaks, many nature reserves with high biodiversity and is considered nationally and internationally important for the conservation of biodiversity associated with oak environments (Ek and Johannesson, 2005; Paltto et al., 2010).

Table 1
Scientific name, redlist status and frequency of the studied lichen species.

Species	Status[a]	Occurrences
Chrysothrix candelaris	Common	210
Chaenotheca phaeocephala	Near threatened	142
Ramalina baltica	Near threatened	37
Cliostomum corrugatum	Near threatened	33
Calicium adspersum	Vulnerable	16
Lecanographa amylacea	Vulnerable	12
Sclerophora coniophaea	Vulnerable	3
Calicium quercinum	Vulnerable	2
Schismatomma pericleum	Near threatened	1
Schismatomma decolorans	Near threatened	0
Caloplaca lucifuga	Near threatened	0

[a] Redlist status according to (Johansson et al., 2010).

The study area consisted mainly of forest 37%, arable land 34%, houses 6% and water 2%. Mean annual temperature, recorded at the nearest weather station (station 8525) is 6.8 °C, and mean annual precipitation is 570 mm (http://www.smhi.se).

All oaks of conservation value had previously been mapped by the local environmental authorities (data previously used in several publication, e.g. (Paltto et al., 2010; Bergman et al., 2012; Musa et al., 2013; Lättman et al., 2014)). In the present study, these data were used to select oaks, between 3.1 m and 4.1 m in circumference. The study area, a 20-by-20 km square, was divided into 400 grid squares; each grid square was 1 km^2. We aimed to select one oak per grid square and, if given a choice, the one closest to the middle of the grid square. Not all grid squares contained trees of suitable size. In total, 213 oaks were selected for field work (Fig. 1). During field work, it was not always possible to locate the targeted tree, based on coordinates and data on circumference, in which case another tree within the size criteria was chosen.

For each target tree, the surrounding density of previously mapped oak was calculated, within 28 different spatial scales (radii of 28–1225 m). Data on arable fields, forest, water and individual houses were extracted from topographic and real-estate maps (Swedish ordnance survey: *GSD Terrängkartan* and *GSD Fastghetskartan*, Lantmäteriet, i2012/898) within each radius around each target tree. Areas registered as streams or lakes were reclassified into water, arable field or other open land was reclassified to arable fields, while coniferous and deciduous forest was reclassified into forest. The amount of house surface was used as a proxy for populated area. The ArcGIS 10 software was used to analyse the spatial data (Nitare and Norén, 1992).

2.3. Field work and oak data

Field work was conducted between July and October in 2010 when the 213 selected oaks were searched for eleven lichen species. For each tree, the entire trunk up to 150 cm above the ground level was carefully searched for the presence of these lichens.

For each target tree, three variables were collected describing the tree and its near surrounding (Table 2): circumference at breast height; sun exposure and density of trees of shrubs near the oak. Sun exposure was recorded by estimating the proportion of light availability through the canopy. The area considered was first divided into North-South as midpoint, and then the proportion of clear sky was visually estimated (Johansson et al., 2009). The density (percentage vertically projected cover) of nearby other trees and shrubs was estimated around each tree within 5 m distance from margin of the canopy of each target tree.

2.4. Data analyses

Effects of 5 landscape variables (oak density and land use such as forest, water, houses and arable fields) and 3 tree variables (circumference, sun exposure, density of nearby shrubs and trees) were analysed for individual species, for each of the 28 different spatial scales, with a binomial generalized linear model (GLM) with logit link function. Oak density and the area of water and houses were square root transformed to down weight extremes and be more evenly distributed. Furthermore, we used GLM with poisson distribution of errors and log link function to analyse the effect of the same variables, and scales, on lichen species richness of oaks. Species richness was defined as the number of the eleven lichen species per oak. Individual GLMs were conducted for three lichens species that were frequent enough for the analysis (*Ch. phaeocephala, Cl. corrugatum, R. baltica*). The remaining 8 species were excluded for being too