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Biodiversity of most dead wood-dependent organisms in thermophilic temperate oak woodlands thrives on diversity of open landscape structures

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ABSTRACT

Oak and mixed deciduous forests with oaks are the most widespread woodland types in the central European lowlands. The aim of this study was to analyse how the biodiversity of saproxylic organisms (fungi, lichens, beetles, and ants, bees and wasps) in thermophilic temperate oak woodlands respond to the openness in landscape structure of tree habitats. We sampled 32 sites in a split-plot design in Krivoklatsko (Czech Republic), which were chosen to include spatial diversity, including dense forests, open forests, woodland edges and solitary trees. A canonical correspondence analyses (CCA) and generalized additive models (GAM) were used for analyses. The results indicated that the taxa studied showed differences in species composition among the studied landscape structures and most taxa preferred more open and light conditions of the woodland environment. We also observed positive effect of the heterogeneity in open landscape structures on biodiversity of saproxylic organisms. As it is recently showed by ecologists, most of the thermophilic oak woodlands are threatened by succession, saproxylic organisms are facing decline throughout the world and traditional forest management (e.g. game keeping, wood pasturing or coppicing) appears to be one solution to mitigate biodiversity loss.

1. Introduction

Many parts of the Earth are facing biodiversity loss and many places important for their biological legacy are negatively affected by the homogenisation and intensification of recent environmental management methods (Vitousek et al., 1997; Dirzo and Raven, 2003). Many species are predicted to be lost before they have been explored for science, and in the best case scenario, specimens are at least currently preserved in several museum collections around the world (Ponder et al., 2001; Horak et al., 2012). The number of threatened species is increasing and these species are losing their former strongholds and survive on the edges of their distribution areas (Channell and Lomolino, 2000). Many formerly common species and their habitats have been vanishing on various landscape scales (Konvicka et al., 2008). However, in contrast, some species are increasing in abundance and distribution (e.g. extralimitally) or are colonising new disjunctive areas (Kloot, 1984). Most probable causes are changes in land use and climate (Horak et al., 2013a).

Woodlands dominated by oaks are recently facing the abandonment of traditional forest management, and the modern forest management of high forests (Peterken, 1993) together with artificial regeneration are probably factors that have jeopardized their maintenance (Mielikainen and Hynynen, 2003). Wide areas of woodlands at lower altitudes have been pastured in the past by domestic animals (cattle, pigs, sheeps and goats), intensively coppiced or coppiced with standards, gathered for litter, used for game keeping and hunting and many disparate management types have created the fine mosaic of woodland patch types in which many species thrive (Vera, 2000; Horak et al., 2012). The abandonment of such management activities and the creation of conservation areas with unmanaged oaks have led to the expansion of early successional tree species such as birch, which shade lower canopy strata and overgrow solitary trees with limbs in the lower canopy (Ranius and Jansson, 2000). A similar problem is observed with maples and ashes on high nutrient soils, beech at high altitudes on mesic (or deep) soils and with conifers (spruce and pine) artificially planted under the oak canopy (Hofmeister et al., 2004; Janik et al., 2011).

The loss of formerly common species is reported also from temperate oak woodland areas (Buse et al., 2007; Hedl et al., 2010). Oak and mixed deciduous forests with oaks are the most

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widespread woodland habitats in the central European lowland and adjacent areas (Svoboda et al., 2011). In the temperate climatic zone, various types of oak woodlands naturally occur up to ca. 600 m a.s.l., especially on dry and semi-dry sites (Neuhauslova, 1998). The majority of European oak species are sun-loving trees, whose recruitment is dependent on favourable micro-climatic conditions during the fruiting stage of mature trees and for seedling growth and development (Rolecek, 2005; Ugurlu et al., 2012). Oaks are also known for their stamina and high quality wood and are often protected as single specimens or monument trees. Furthermore, acorns are nutrient-rich feed for domestic and semi-domestic animals such as pigs or wild boars (Vera, 2000). Veteran oaks are one of the most suitable hosts for organisms that are dependent on dead wood (Svoboda et al., 2011; Alexander, 2013).

Organisms dependent on dead wood, like beetles and fungi, have recently been the focus of forest ecology (Lindhe et al., 2005; Buse et al., 2007; Norden et al., 2008). These organisms are highly interconnected with woodland habitat types and many are bioindicators (Svoboda et al., 2010). Studies performed at the species level have shown that the openness of the surrounding woodland environment often leads to an increase in species population density (Buse et al., 2007). A similar situation is observed in studies at guild or family levels, where most taxa thrive on canopy openness (Lindhe et al., 2005; Horak and Rebl, 2013). Although a gap remains in the knowledge of multi-taxon responses, and non-boreal landscapes are under-represented with respect to the number of studies. Namely, species diversity is much higher in temperate and Mediterranean woodlands, and oak-dominated or mixed woodlands are European hot-spots of biodiversity (Blasi et al., 2010; Buse et al., 2010). Solitary oak trees are known to be very rich with respect to the number of species of disparate organisms (Svoboda et al., 2010). Nevertheless, the responses of dead wood-dependent organisms to environmental changes can be of high interest for suitable biodiversity management activities.

The aim of this study was to analyse how the biodiversity of saproxylic organisms responds to the openness and diversity in landscape structure of tree habitats in thermophilic temperate oak woodlands, using a multi-taxa approach.

Namely, we focused on (i) species composition, (ii) richness and (iii) its trends of four taxa (fungi, lichens, beetles, and ants, bees and wasps) and their influencing by four landscape structures (solitary trees, woodland edges, open forests and dense forests).

2. Methods

2.1. Study area

Krivoklatsko is situated in the western part of the Central Bohemian range about 20 km west of Prague (coordinates: 50.00N; 13.88E). It is known within the Czech Republic for a high biodiversity, which has recently been highlighted by attempts to protect this area as a national park (Hula, 2009). Its large area (ca. 630 km^2) of low and medium altitudes (ca. 400 m a.s.l.) contains diversified land use, geomorphology and a large number of disparate nature conservation and cultural heritage areas, such as Krivoklatsko UNESCO Biosphere Reserve and Krivoklatsko Protected Landscape Area, with nearly 30 small-area protected sites. Krivoklatsko is one of the most forested parts of the Czech Republic, with 62% covering by forests (Hula, 2009).

2.2. Study taxa

We studied four taxa: fungi (Fungi), lichens (Lichenes), beetles (Coleoptera) and ants, bees and wasps (Hymenoptera: Aculeata). Only species with an affinity for dead wood habitats (hereafter called saproxylics) were evaluated. For beetle species, all obligate saproxylics were taken into account (Schmidl and Bußler, 2004). All dead wood-dependent fungal species (Hagara et al., 2005) were analysed, except those with corticioid fruiting bodies; pyrenomycetes and inoperculate discomycetes with small apothecia were also not sampled. Most saproxylic species of hymenopterans use dead wood for nesting and some are able to build nests in other substrates, thus, we only evaluated species with a predominant dead wood strategy (Macek et al., 2010). The associations of lichens with dead wood substrates in central Europe are more complicated than for the other studied taxa (Jansova and Soldan, 2006). As lichens are mostly long-lived organisms, it is often hard to determine whether a species is associated only with a living tree (i.e. arboricolous) or is more opportunistic and dependent only on substrates generated by wood plants. Therefore, we used all lichen species in our analyses that were found on dead and partly living wood, because most trees in old-growth forests include many dead wood microhabitats (Winter and Moller, 2008).

2.3. Sampling of taxa

Fungi and lichens were sampled using circular plots with a radius of 20 m surrounding the traps (area 1256 m^2). For solitary trees, the shape of the sampling plot was adapted to the tree-dominated habitat in the surroundings, but also had a fixed total area. The centre of the sampling plot was 20 m from the edge of the woodland for the edge category. Fungi were sampled four times in June, September and October 2011 and May 2012. Lichens were sampled once during August 2011. Beetles and hymenopterans were sampled using large window trunk tree traps (Horak, 2011), which are known to be highly effective for trapping dead wood associates including flightless fauna (Horak et al., 2013b). The traps were active and regularly emptied during the 2011 vegetation season (May–September).

2.4. Study environmental variables and their sampling

Our study focused on four main landscape structures of tree habitats:

(i) solitary trees (canopy openness: mean = 32.51% ± 4.57 SE) with mean distance of 94.75 m (SE = 22.22 m) from the nearest forest edge and high coverage of plants and shrubs in the understorey,
(ii) natural woodland edges (32.05% ± 5.92 SE) between forest and non-forest area (grasslands and arable land) with medium coverage of plants and shrubs in the understorey,
(iii) forests with open canopy conditions (32.87% ± 4.05 SE) and medium coverage of plants and low coverage of shrubs in the understorey,
(iv) dense forests with closed canopy conditions (12.88% ± 0.68 SE) with low coverage of plants and absence of shrubs in the understorey.

First three landscape structures (i–iii) reflected different open canopy conditions and one (iv) reflected closed canopy conditions.

In total, we sampled 32 sites that were designed as split plots – i.e. eight whole plots contained all four landscape structures. Three pairs of whole plots were distributed in or near three protected areas recently listed (www.pralesy.cz) as the most natural woodlands in the Czech Republic (Brdatka, Nezabudicke skaly and Na Babe) and two pairs between protected areas Jouglovka and Kohoutov. The main reason for this choice was natural or semi-natural tree species composition of above mentioned protected areas and their surroundings (Nemec and Lozek, 1996).