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Butterflies take advantage of contemporary forestry: Clear-cuts as temporary grasslands

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ABSTRACT

Contemporary forest landscapes in boreal and temperate environments, harvested by clear-cutting, contain various novel types of open spaces which are potentially suitable for species inhabiting natural or semi-natural open habitats. However, systematic analyses identifying the share of the regional species pool that can take advantage of this opportunity are missing. We assessed the importance of such forest openings for open-habitat butterflies in Estonia in Northern Europe by comparing butterfly species richness and composition in forest clear-cuts with their regional species pool. The species richness of butterflies in clear-cuts appeared to be remarkably high: we recorded altogether 81% of the total regional species pool across the study sites. Clear-cuts were inhabited by a very high share (79%) of regionally occurring grassland species, as well as nearly complete sets of open-habitat generalists and forest species. Redundancy analysis showed that clear-cuts in forests with different environmental characteristics harbour distinct butterfly assemblages, their contribution to the butterfly fauna in forest landscapes being thus complementary. This as well as several other lines of evidence indicate that most butterfly species can form resident populations in harvested forest landscapes. Our findings demonstrate that considering novel types of forest openings as 'temporary meadows' can substantially improve the conservation prospects for butterflies and other organisms that have traditionally been considered to inhabit grasslands and other open habitats in agricultural landscapes. Human-altered ecosystems may thus prove to be a viable alternative where restoring or maintaining natural and semi-natural habitats is impossible.

1. Introduction

Changes in land use and management practices during the last century have led to a dramatic decrease of natural and semi-natural open habitats in agricultural landscapes across Europe (Hooftman and Bullock, 2012; Cousins et al., 2015). The loss and fragmentation of such habitats, mostly either due to agricultural intensification or afforestation, continue to pose a major threat to many organism groups (Helm et al., 2006; Brambilla et al., 2010; Krauss et al., 2010; Marini et al., 2010; Van Swaay et al., 2010). Various conservation practices have been proposed and applied to prevent the decline and extinction of populations associated with these habitats, ranging from more biodiversity friendly forms of agriculture to the establishment of nature reserves and habitat restoration (Winqvist et al., 2011; Woodcock et al., 2012; Arponen et al., 2013). However, the effectiveness of such practices is often limited due to the influence of land-use changes in the wider landscape surrounding protected or managed habitats (Schneider and Fry, 2001; Filz et al., 2012; Öckinger et al., 2012). Moreover, the maintenance and restoration of traditional landscapes and habitats are often associated with high socio-economic costs.

Taking advantage of human-altered ecosystems (i.e. novel, impacted or designed ecosystems, see Morse and Pellissier, 2014, for classification) may provide another opportunity to mitigate the loss of natural and semi-natural habitats (Hobbs et al., 2006; Lundholm and Richardson, 2010). Although intensive land-use and industrial activities can heavily modify environments, conditions in some of those changed areas are similar to those in more natural ecosystems (Lenda et al., 2011; Tropek et al., 2013). Indeed, various landscape elements that have started to be increasingly common relatively recently (e.g., mining areas, railway embankments, power line corridors) have been shown to offer alternative habitats for multiple open-habitat species (Řehounková and Prach, 2010; Lensu et al., 2011; Tropek et al., 2013; Moroń et al., 2014).

Novel types of open habitat areas, such as clear-cuts and various right-of-ways (e.g., power and gas line corridors), have become increasingly common also in forest landscapes. In many boreal and temperate regions, the area of open habitats in managed forests exceeds by far the area of semi-natural grasslands

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(Peterken and Francis, 1999, this study). There is accumulating evidence that these forest openings are also of benefit to many grassland species, such as e.g., plants (Peterken and Francis, 1999; Pykälä, 2004; Aavik et al., 2009), orthopterans (Sliacka et al., 2013) and butterflies (Ibbe et al., 2011; Fartmann et al., 2013; Korpela et al., 2015). For example, in Northern Europe, grasslands in forest landscapes support higher species richness and abundance of butterflies than those in intensively managed agricultural landscapes (Kuussaari et al., 2007a; Bergman et al., 2008; Jonason et al., 2010). Also, forest edges and clear-cuts at the forest edges have been shown to offer increased floral resources for adult butterflies and favourable microclimatic conditions for larval development (Kuussaari et al., 2007a; Van Halder et al., 2010; Korpela et al., 2015).

Despite the growing appreciation of heterogeneous forest landscapes as important butterfly habitats, we still lack analyses systematically investigating the composition of butterfly assemblages in forest openings. Such an analysis would be particularly useful for conservation planning: identifying the share of the regional species pool that finds habitat in forest openings may allow for more focused protection of species that do not benefit from managed forest landscapes. This study was undertaken to investigate butterfly assemblages in clear-cuts, the most plentiful type of open space in managed forest landscapes in Northern Europe. Our primary aim was to compare butterfly species richness and composition with their regional species pool. Our focus was on open-habitat species, and those characteristic for semi-natural grasslands in particular. We also investigated if clear-cuts in forests with different characteristics harbour different butterfly assemblages, i.e. if their contributions to the entire butterfly fauna in forest landscapes are complementary.

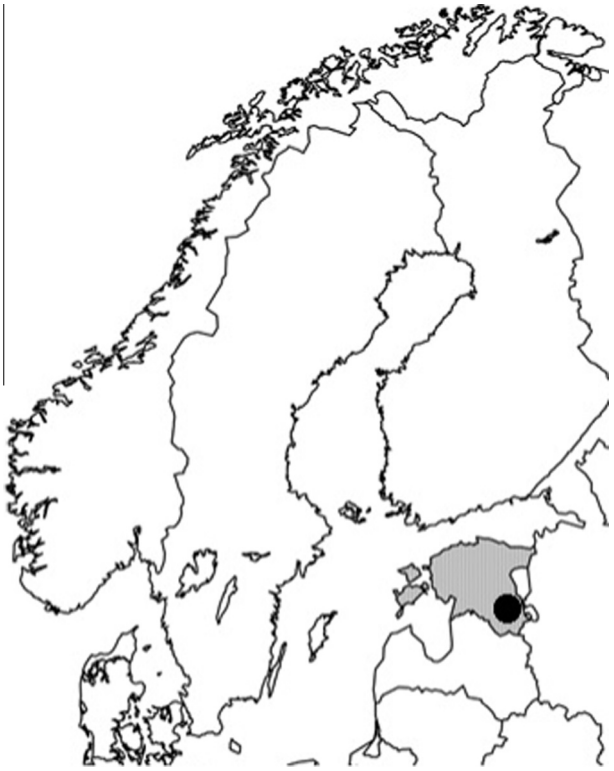

Fig. 1. Map showing the location of the study region in Estonia, Northern Europe. See Appendix A, for spatial configuration of the study sites and their soil moisture levels.

2. Material and methods

2.1. Study sites

Species richness and composition of butterflies in forest clear-cuts were investigated in an area of up to 50 km from the city of Tartu, Eastern Estonia (58°23′N 26°43′E; Fig. 1). Forests cover approximately 46.5% of the area in the study region (calculated using the data in Raudsaar et al. (2014)). Most of the forests in the study region are managed by clearcutting (Raudsaar et al., 2014) with the retention of solitary trees (=green-tree retention cutting; Rosenvald and Lõhmus, 2008). In the study region, clear-cuts in a favourable age range for butterflies (roughly 2–10 years; see also Fartmann et al., 2013) cover about 6% of the total land area (calculated using the data for the years 2004–2013 in Raudsaar et al. (2014)). Less than two year old clear-cuts do not provide larval and adult resources for butterflies, whereas older clear-cuts become gradually overgrown. For comparison, semi-natural grasslands in the study region cover just about 12% of the area of clear-cuts (calculated using the database of semi-natural grasslands of the Estonian Seminatural Communities' Conservation Association, data from 2000 to 2008). The area of semi-natural grasslands in Estonia has substantially declined in the last half-century and is likely to decline further (Sang et al., 2010), whereas the annual rate of clearcutting has been relatively stable or even increased, being an average of 1% of the total forest area during 1999–2013 (calculated using the data in Raudsaar et al. (2014)).

Altogether 35 clear-cuts were chosen for this study from amongst the ones in main forest areas in the study region. The primary selection of clear-cuts was made using orthophotos provided by the Estonian Land Board (http://xgis.maaamet.ee, accessed in 2012). Clear-cuts directly adjacent to semi-natural grasslands were avoided to minimize any direct influence of these nearby butterfly habitats to the clear-cuts' fauna. Clear-cuts were chosen from areas covered by three main managed forest type groups (oligo-mesotrophic boreal, mesotrophic boreal and eutrophic boreo-nemoral forests; Paal, 2002; Fig. 2), roughly proportionally to the share of these forest type groups in the study area.

For each clear-cut, we estimated five parameters as potentially important for butterfly species richness and composition: its area, age, distance to the nearest semi-natural grassland, soil pH and moisture. The two former parameters, clear-cut area (0.3–2.5 ha, 1.2 ha on average) and distance to nearest grassland (30–1000 m, mostly over 100 m, 423 m on average), were measured from orthophotos. Clear-cut ages (i.e. years since logging; 2–10 yrs, 5.5 yrs on average) were obtained from the Estonian Forest Registry (http://register.metsad.ee/avalik/, accessed in 2012). The soil characteristics (pH and moisture) were considered because of their potential influence on butterfly community composition through their impact on plant communities. To determine soil pH and moisture, clear-cuts were first assigned to a forest site type according to the Estonian Forest Registry (http://register.metsad.ee/avalik/, accessed in 2012). These forest site types distinguish by a characteristic combination of soil pH and moisture level. The average values of soil pH and moisture, derived from the ordination scheme of forest site types by Lõhmus (2004), were used to quantify these parameters in the selected clear-cuts (pH: 3.3–7.3, 5.4 on average; moisture: 2.8–5.5, 4.3 on average). In general, forest site types belonging to the same forest type group are relatively more similar in these parameters. In particular, eutrophic boreo-nemoral forests are generally most moist and least acidic of the three, whereas oligo-mesotrophic boreal forests are the driest and most acidic (Lõhmus, 2004).

2.2. Butterfly surveys

Repeated surveys were carried out to determine species composition and richness of butterfly communities in the chosen