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# Power-line corridors as source habitat for butterflies in forest landscapes

Åke Berg [a,*], Karl-Olof Bergman [b], Jörgen Wissman [a], Michał Żmihorski [c,d], Erik Öckinger [c]

[a] Swedish University of Agricultural Sciences, Swedish Biodiversity Centre, Box 7016, SE 750 07 Uppsala, Sweden
[b] IFM Biology, Conservation Ecology Group, Linköping University, SE 581 83 Linköping, Sweden
[c] Swedish University of Agricultural Sciences, Department of Ecology, Box 7044, SE 750 07 Uppsala, Sweden
[d] Institute of Nature Conservation, Polish Academy of Sciences, Mickiewicza 33, 31120 Kraków, Poland

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ABSTRACT

Modern intensified agriculture has decreased farmland heterogeneity, which has led to strong negative effects on farmland biodiversity. However, partly forested landscapes seem to offer many alternative habitats for open habitat species such as butterflies, since modern forestry and development of infrastructure has created several new environments such as forest road verges and power-line corridors. The aim of the present study was to investigate the importance of power-line corridors (PLCs) as butterfly habitats by testing i) if species richness and abundance of butterflies in PLCs are affected by adjacent habitat composition (i.e. comparisons of PLCs with different adjacent habitats), ii) if PLCs act as source habitat through spill-over of individuals into adjacent forest roads and semi-natural pastures and iii) if species composition differs among the investigated habitat types. To investigate this we censused the butterfly fauna in 23 study landscapes in south-central Sweden. We found support for the hypothesis that PLCs may act as source habitats for butterflies in forest roads and pastures, since species richness and abundance were decreasing with increasing distance to PLC from 0 to 500 m. In addition, the species composition in forest roads and pastures close to and far from PLCs was similar, suggesting that this increase was not due to an increase of PLC specialists in the other two habitats. Thus, we have shown that PLCs in themselves are important butterfly habitats independently of adjacent habitat composition (adjacent mature forest, clear-cuts or arable land), and they contribute to increased species richness and abundance of butterflies in surrounding areas over 10 times larger than their own width.



## 1. Introduction

Modern intensified agriculture has decreased farmland heterogeneity (Benton et al., 2003). Open semi-natural grassland and other non-crop habitats have been converted into arable land, and field size has increased, which has created vast areas of crop monocultures without field borders such as hedgerows, ditches and stonewalls (Marshall and Moonen, 2002). Furthermore, management of arable fields surrounding the remaining non-crop habitats has been intensified with use of pesticides and fertilizers (Ihse, 1995; Stoate et al., 2001). These landscape changes have had strong negative effects on farmland biodiversity (Krebs et al., 1999; Öckinger and Smith, 2006; Billeter et al., 2008). Moreover, extensive farming has ceased in many farms in forested landscapes, which also have had negative effects on farmland biodiversity in these heterogeneous landscapes (Wretenberg et al., 2007; Uchida and Ushimaru, 2015).

Partly forested landscapes, covering large parts of northern Europe, seem to offer more habitats for species normally found in extensive farmland than landscapes dominated by arable land (Tikka et al., 2001; Bergman et al., 2004, 2008; Söderström, 2009; Söderström and Karlsson, 2011; Öckinger et al., 2012a, 2012b). Modern forestry and development of infrastructure have created several new potential environments for open habitat species in forest-farmland mosaic landscapes. These include clear-cuts and linear elements such as road verges and power-line corridors (Saarinen et al., 2005; Jonason et al., 2010; Berg et al., 2011; Ibbe et al., 2011; Blixt et al., 2015). In general, the human-created habitats mentioned above offer large areas of open extensively managed habitats (Wojcik and Buchmann, 2012). The power-line corridors (PLCs) stretch like wide corridors through the landscape potentially providing wildlife with extensively managed open habitats (Russel et al., 2005). PLCs are kept open by regular clearing of shrubs and young trees (every 6–8 years in our study region). This management creates conditions for a species-rich plant community similar to that in extensively managed grasslands. In contrast to many conventionally managed grasslands where grazing intensity is often too high for many species (Sjödin et al., 2008), the management of PLCs creates good conditions for many flower-visiting insects (Berg et al., 2013). PLCs in Sweden have a total area of 300,000 ha, which is of the same order of magnitude as all semi-natural grasslands combined (Grusell and Miliander, 2004; Jordbruksverket, 2008). Therefore the

* Corresponding author.
*E-mail address:* Ake.Berg@slu.se (Å. Berg).

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importance of PLCs to biodiversity conservation has gained interest during recent years (Russel et al., 2005; Berg et al., 2011) and several studies have investigated the use of power-lines by birds, bees, butterflies and other taxa (King and Byers, 2002; Hollmen et al., 2008; Clarke and White, 2008; Berg et al., 2013).

Power-line corridors have recently been suggested to be important habitats for open-habitat species such as butterflies (Forrester et al., 2005; Lensu et al., 2011; Komonen et al., 2013). In earlier studies, restricted to a region in central Sweden, we have shown that PLCs surrounded by mature forest have a higher species richness and abundance of day-flying butterflies than semi-natural pastures, clear-cuts and forest roads (Berg et al., 2011, 2013). Analyses of different ecological characteristics suggested that early flying species and species with poor or intermediate dispersal abilities were more common in PLCs than in semi-natural pastures and forest roads (Berg et al., 2011). Many species that inhabit the PLCs are associated with open grasslands with shrubs and nectar resources (flowering plants) as well as different typical grassland host plants for the larvae.

Thus, PLCs have contributed to an increased area of open grassland habitat and potentially also increased the connectivity between other grassland patches. Therefore, butterfly populations in habitats such as forest roads and remaining scattered semi-natural pastures could potentially be supported by PLCs, i.e. PLCs might act as a "source habitat" through a spill-over of individuals into adjacent habitats, although this has not been investigated. Similar source effects have earlier been shown for semi-natural grasslands that increased species richness of butterflies in adjacent linear field margins (Öckinger and Smith, 2007). Thus, negative effects of isolation of semi-natural grassland can potentially be counteracted if alternative habitats for reproduction or possibilities for dispersal among patches are found in the landscape (Eycott et al., 2012; Öckinger et al., 2012a, 2012b). However, all butterfly species have different habitat requirements (Dennis, 2010), and it is therefore difficult to predict for which species, and to what extent PLCs in different landscape types may contribute to increase species richness or abundance in other surrounding habitats.

Furthermore, the value of PLCs with different adjacent habitat composition has not been investigated so far, but species richness and abundance of butterflies in PLCs could be influenced by the amount of forest and arable land in adjacent areas, since this has been found for other habitats (Öckinger et al., 2012a, 2012b).

The two main aims of the present study were i) to investigate if PLCs with their high density of butterflies act as source habitat for butterflies in adjacent forest roads and pastures and ii) to investigate if the value of PLCs for butterflies is affected by adjacent habitat composition. First, we analysed if the species richness and abundance of butterflies in the three PLC types differed from pastures and forest roads and if richness and abundance were affected by adjacent habitat composition (i.e. adjacent habitats composed of mature forest, clear-cut or arable fields). Secondly, we analysed if species richness and abundance of butterflies in the two other habitats (forest roads and semi-natural pastures) were influenced by the distance from PLCs. Thirdly, we analysed to what degree species composition differed among the investigated three main habitats, and whether distance to PLC and adjacent habitat composition affected butterfly communities. We investigated this by censusing the butterfly fauna in 160 transects in PLCs, forest roads and semi-natural pastures (below called pastures) in 23 study landscapes in south-central Sweden. We predicted that the species richness in PLCs should be dependent on type of adjacent habitat, i.e. positive effects of adjacent clear-cuts and negative effects of adjacent arable fields compared to mature forests. We also predicted that the butterfly fauna in forest roads and pastures close to PLCs should be more species-rich (and have a higher overall abundance), than sites situated more distant from PLCs, and that the species composition in sites close to PLCs should be more similar to that in PLCs.

## 2. Methods

### 2.1. Study areas

We selected study areas in six regions in south-central Sweden: east of Linköping, west of Linköping, west of Örebro, west of Uppsala, east of Uppsala and west of Norrtälje (see Fig. 1). Four landscapes were selected in each region (only three landscapes in the region west of Uppsala). Seven transects (200 m) were placed in each of the 23 landscapes (except one landscape with six transects, Fig. B1–3).

We selected transects in the following three habitat types in each landscape: PLCs, forest roads and pastures. We distinguished three types of PLCs: PLCs in forested landscapes (>80% of forest within 1 km of the transects) with adjacent mature forest (>20 years old; hereafter referred to as PLC.mature.forest), PLCs in forested landscapes (>80% of forest within 1 km of the transects) with adjacent open clear-cuts (>50% of transect length) at the border (PLC.clearcut) and PLCs situated in a mosaic landscapes with arable fields (60% of forest within 1 km of the transects) (PLC.mosaic). Pastures and forest roads were selected according to their distance to closest PLC (those situated close to (<500 m) and far from (>500 m) a PLC), see Table 1. See Fig. B4 for an illustration of the study design. However, in five cases (two transects in pastures and three transects in forest roads) we could not find suitable sites within 500 m from power-line corridors. In these cases we selected sites as close to PLCs as possible and the sites far from PLC were always situated further from the PLCs than the sites that were close to PLCs.

In total 160 transects were included in the study and all transects were situated at least 300 m apart. Transects in PLCs were situated both in wide PLCs (53%; 60–200 m), and in narrower (47%; 25–55 m) regional power line corridors (the width did not differ between the three PLC types, ANOVA, $df = 2$, $p = 0.8$), and sites at different successional stages (i.e. with different coverage of shrubs and trees) were included. Transects in pastures (uncultivated and unfertilized, on dry-mesic ground conditions with natural vegetation) were mainly located in grazed pastures ($n = 42$) and in a few cases ($n = 3$) in recently abandoned (but not overgrown) pastures. The pastures varied in size (mean $\pm$ SE $= 11.8 \pm 1.4$ ha) and included both open pastures and pastures partly covered with trees and shrubs. The availability of pastures close to PLCs was a limiting factor and almost all pastures close to PLCs in the selected landscapes were included in the study, while the pastures far from PLCs were a random sample of several available pastures in each landscape. The selected forest roads were mostly surrounded by forest (96%), and to a smaller degree by open habitats such as clear-cuts (4%). The mean ($\pm$SE) width of the roads (including the road verges) was 9.1 ($\pm$0.2 m), i.e. in some sites small parts of the adjacent forest were included in the 10 m wide transects (see below). The traffic was of low intensity (all gravel roads and very few cars seen during censuses) and mortality due to collisions with vehicles is not high in such roads (Skórka et al., 2015). Most roads had verges with grassland vegetation and shrubs (1–5 m) that usually are cut once every year.

The forests in the surrounding landscape (mainly production forests) were dominated by spruce (*Picea abies*) and Scots pine (*Pinus sylvestris*), but birches (*Betula pendula* and *B. pubescens*), aspen (*Populus tremula*) and rowan (*Sorbus aucuparia*) were also relatively common in mixed forests.

### 2.2. Butterfly censuses

Butterflies (Papilionoidea and Hesperioidea) and day-active burnet moths (Zygaenidae), in the following collectively referred to as "butterflies", were observed along a 200 m transect. All transects were visited four times in total, once during each of the following periods: 15 May–3 June, 4–23 June, 24 June–13 July and 14 July–2 August 2014 in order to cover the seasonal variation in species flight periods. The total number of individuals (sum from 4 visits) for each species was used in