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Clear-cuts in production forests: From matrix to neo-habitat for butterflies

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ABSTRACT

Butterfly conservation in Europe is mainly focused on well-defined grassland habitat patches. Such an approach ignores the impact of the surrounding landscape, which may contain complementary resources and facilitate dispersal. Here, we investigated butterfly species richness and abundance in a habitat normally regarded as unsuitable matrix: production forestry clear-cuts. Butterflies were recorded in 48 clear-cuts in southern Sweden differing with regards to the time since clear-cutting and land-use history (meadow or forest based on historical maps from the 1870s). All clear-cuts had been managed as production forests for at least 80–120 years. A total of 39 species were found in clear-cuts of both land-use histories, but clear-cuts with a history as meadow had on average 34% higher species richness and 19% higher abundance than did clear-cuts with a history as forest. No effect of the time since clear-cutting was found, irrespective of land-use history, which was likely due to the narrow timespan sampled (<8 years). The absence of temporal effect suggests that clear-cuts may provide butterflies with valuable resources for 10–15 years. Assuming a 100 year forest rotational cycle, this means that 10–15% of the total forested area are made up by clear-cuts valuable to butterflies, which corresponds to an area about four times as large as that of species-rich semi-natural grasslands. The study illustrates the importance of considering land-use legacies in ecological research and question the landscape-ecological view that clear-cuts make up an unsuitable matrix for butterflies. Moreover, forest conservation management with special attention to land-use history may increase the quality of the landscape, thus facilitating butterfly metapopulation persistence. Given their large area and assets of nectar and host plant resources, clear-cuts must be considered as a butterfly habitat in its own right. Being a man-made environment with short history, we might call it a neo-habitat.

1. Introduction

European butterflies have suffered substantial losses over the last century (van Swaay et al., 2006). Currently, one third of the populations are experiencing declines and several species have gone locally, regionally and nationally extinct (Bergman et al., 2004; van Swaay et al., 2010). Habitat loss and fragmentation are main factors threatening the European butterfly fauna (Brückmann et al., 2010; Öckinger et al., 2012). This is, to a great extent, due to changes in land-use where industrialized forms of agriculture and forestry have expanded on behalf of traditional land-use methods known to affect butterfly populations positively (Bergman, 2001; Dover et al., 2011; Schneider and Fry, 2005).

Butterfly conservation is often focused on single areas with well-defined borders, e.g., semi-natural grasslands (van Swaay, 2002). Thus, the significance of surrounding environments, often referred to as the unsuitable matrix, for the survival of butterfly populations at landscape levels is seldom accounted for (Bergman et al., 2008; Öckinger et al., 2012; Ricketts, 2001). Dennis et al. (2006, 2003) proposed a resource-based definition of habitat to conserve butterflies where the functional and behavioural use of resources is acknowledged irrespective of vegetation type: a challenge to the habitat patch vs. matrix view of the landscape. Power line corridors, road verges, clear-cuts and ditches are often considered as matrix although they may mitigate negative effects of habitat loss and isolation (Berg et al., 2011; Jonason et al., 2010). A resource-based approach to conservation, acknowledging prime as well as secondary habitats, may therefore be more efficient in facilitating metapopulation persistence compared to a single-habitat approach (Dennis et al., 2006, 2003; Doerr et al., 2011;

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Hodgson et al., 2011; Vandermeer and Carvajal, 2001), specifically for the species for which our understanding of their utilization of the landscape is poor.

Clear-cuts may be of particular importance for the conservation of butterflies, but is seldom recognized as such. In the early successional stage of a clear-cut the herb layer increases rapidly (Pykälä, 2004), offering the butterflies a sunlit environment with nectar and host plant resources. These resources increase the quality of the landscape and enable a greater exchange of individuals between metapopulations. The importance of clear-cuts to butterflies may explain the higher species richness found in patches of semi-natural grasslands embedded in forested compared to in arable landscapes (Bergman et al., 2008; Krämer et al., 2012; Öckinger et al., 2012). Also other species besides butterflies benefit from clear-cuts. For example, the Red-Backed Shrike (*Lanius collurio*), which traditionally has been regarded as a typical farmland bird species, has shifted its primary habitat from grassland to clear-cuts as a consequence of rapid land-use changes (Söderström and Karlsson, 2011). Clear-cuts may therefore be seen as a possible complement to species-rich grasslands in conservation (Jonason et al., 2010).

Current conservation efforts focussing on already biodiversity-rich habitats do not seem to be sufficient to preserve threatened species as many continue to decline (Hochkirch et al., 2013). A greater effort towards exploring and utilizing potential resources outside the traditional habitat patches must be made in order to increase the amount of suitable environments and to decrease fragmentation effects. Furthermore, land-use history hundreds of years back in time has been shown to affect contemporary biodiversity and this may add an extra dimension to spatial planning of conservation work (Szabó and Hédl, 2011). Recently, Ibbe et al. (2011) found a century-old legacy of former grassland management on butterfly assemblages in newly created clear-cuts in Sweden. However, as the quality of clear-cuts decreases with time due to afforestation and regrowth, it is important to know for how long the positive effects remain in order to better understand the dynamics of the landscape and how this, in turn, affects the butterflies. Therefore, the aim of the study was to investigate to what extent and on what temporal scales butterflies are utilizing Swedish production forestry clear-cuts and to what extent this is affected by land-use history.

2. Material and methods

2.1. Study area and selection of study sites

The study area was located in the province of Östergötland, southern Sweden (N57° 43′-58° 15′; E15° 00′-15° 40′). In 2013, a total of 48 production forestry clear-cuts were chosen as study sites, half of which had a land-use history as meadow and the other half as coniferous forest. The site selection was made using contemporary maps of clear-cuts together with regional land-use maps from the 1870s displaying, e.g., coniferous and deciduous forests, arable fields and hay meadows. A clear-cut was defined as having a land-use history as meadow if at least 15% of its total area was covered by meadow on the historical maps. Clear-cuts defined as having a history as forest were fully covered by forest. Since possible management recommendations will be made at the clear-cut level, we included the whole clear-cut as study site and not only the part formerly being meadow. The exact year of conversion from meadow to production forest is not known, but occurred at least 80–120 years ago, corresponding to one rotational cycle in south-Swedish production forestry. Forest grazing by cattle may have been practised in the clear-cuts initially, but most likely no longer than until the 1930s as the Swedish Government then raised demands for more intensified timber production (Kardell, 2004).

The time since clear-cutting varied between 2 and 4 years (24 clear-cuts) and 6–8 years (24 clear-cuts), with equal number of clear-cuts from both land-use histories in each time class, allowing us to analyse temporal effects using a space-for-time substitution. 2–4 years after clear-cutting is when the butterflies are expected to peak before they decline in numbers due to forest regrowth (Komonen et al., 2013; Palviainen et al., 2005). The older clear-cuts have previously been surveyed by Ibbe et al. (2011). The size of the clear-cuts varied from 1.5 to 6.6 ha (Table 1).

2.2. Butterfly recordings

Recorded butterflies included species from the superfamily Papilionoidea and the families Hesperiidae and Zygaenidae. These are henceforth referred to as “butterflies”. Species names follow Eliasson et al. (2005). The butterflies *Leptidea sinapis*/*Leptidea reali* and *Plebejus idas*/*Plebejus argus* were grouped together due to difficulties of identifying them to species level in the field.

All study sites were visited three times throughout the summer of 2013, once within each of the periods June 3 to 12, June 17 to July 11, and July 17 to August 3. The recording took place only at temperatures above 17 °C and under predominantly sunny conditions, with winds of up to level 4 on the Beaufort scale. If the sun disappeared behind clouds, butterfly recordings came to a halt until the sun reappeared. However, if the temperature exceeded 22 °C, recordings could be carried out during some cloudiness as well (Wikström et al., 2009). There is a trade-off between number of visits and number of recorded species (Jonason et al., 2014a); with three visits spread over the season under suitable weather conditions it was expected that approximately 75% of the regional butterfly fauna would be found (Wikström et al., 2009), which is sufficient for making reliable analyses of data (Roy et al., 2007).

Transect lines were placed perpendicular to the longest axis of the clear-cuts and spaced 25 m apart. All butterflies within an area of 5 m in front, 5 m to each side and 5 m up in the air were identified to species level (Pollard and Yates, 1993). With this method 40% of each clear-cut was covered. If species identification could not be made in flight, a hand net was used to catch the butterflies. All transect lines were walked at a constant pace of 50 m min^{-1}. The time of day during which the recording took place varied for each clear-cut between the three survey occasions, but always occurred between 09:00 and 17:00 (Central European summer time, UTC+2). The recording stopped 5 m prior to and continued 5 m after roads and ditches crossing the clear-cuts in order to avoid catching butterflies drawn to attractive neighbouring habitats rather than the actual clear-cut. Permits for conducting field work were not required based on the open-land policy of the Swedish Government (allemansrätten). All species were, if captured, immediately released after identification in field and the capturing did not involve any protected species.

2.3. Habitat factors

Several habitat factors were measured in the 48 clear-cuts in order to be able to control for plausible confounding factors between the two clear-cut categories (i.e., meadow and forest history) in the analyses (Table 1). A total of 33 circles with a radius of 5.64 m (i.e., 100 m^2) were evenly placed over the clear-cuts along the butterfly recording transects. Within the circles, the coverage of exposed mineral soil, woody debris and bare rock were visually estimated. All living trees, stumps and snags >10 cm in diameter were identified to species level and their basal area was assessed in order to estimate the tree cover before logging. All clear-cuts were located >300 m from the closest existing semi-natural grassland