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Evaluating forest clear-cuts as alternative grassland habitats for plants and butterflies

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ABSTRACT

Temperate semi-natural grasslands in Europe and East Asia have been rapidly declining and their conservation is urgently required. Although recent studies have indicated the importance of clear-cuts as alternative habitats for grassland butterflies, there is paucity of studies that directly compare biodiversity and habitat quality between grasslands and clear-cuts using multiple taxa. In this study, we compared the plant and butterfly richness between grasslands and clear-cuts, with a focus on the distribution of butterfly resources (nectaring flowers and host plants) and endangered plant and butterfly species, in a cool temperate area of central Japan. We established three or six transects in five grassland and five clear-cut sites, and measured the richness of plants and butterflies and environmental variables such as vegetation height and coverage at both transect and site levels. At the site level, there were no differences in the richness of all plants, butterflies, and butterfly host plants, but there were significant or marginal differences in the richness of endangered plants, butterflies, and butterfly host plants. Almost all endangered plants and butterflies were found in the overall grasslands, but only half of the endangered butterfly species were observed in the overall clear-cuts. At the transect level, species richness of endangered plants and butterflies peaked at an intermediate vegetation height. Our results indicate the primary importance of existing semi-natural grasslands and the necessity of management when the vegetation becomes too high. We recommend active creation of clear-cuts near or between the existing grasslands, so that clear-cuts can provide source or backup populations and act as stepping stones to connect the isolated grassland populations.

1. Introduction

Exploring the conservation measures of endangered ecosystems is an important issue in conservation biology (Primack, 2004). It is particularly required for the temperate semi-natural grasslands in the climatically forested zones of Europe and East Asia. This is because these ecosystems have been rapidly declining due to both agricultural intensification and abandonment, and consequently the component species are now highly endangered (Choi and Kim, 2012; Dengler et al., 2014; Habel et al., 2013; Nakamura, 2011; van Swaay, 2002; van Swaay et al., 2006; WallisDeVries et al., 2002). In addition, although these ecosystems have been conventionally viewed as human artifacts and depend on human intervention for their persistence (Vera, 2000; Weigl and Knowles, 2014), recent studies have stressed that the flora and fauna of the temperate semi-natural grasslands are natural, ancient, and evolutionarily distinct in temperate Europe (Kajtoch et al., 2016; Pärtel et al., 2005; Svenning, 2002; Vera, 2000), North America (Weigl and Knowles, 2014), and East Asia (Ushimaru et al., 2018). Therefore, the conservation of species that depend on semi-natural grasslands is essential to maintain not only biodiversity but also distinct lineages in these regions.

Owing to the difficulty in halting the decline of semi-natural grasslands, modern open biotopes, such as clear-cuts, firebreaks, road verges, and power-lines have recently attracted attention as alternative habitats for grassland species in temperate and boreal regions (Berg et al., 2011, 2016; Russell et al., 2005; Saarinen et al., 2005; Viljur and Teder, 2016). Although these biotopes have classically been considered as negative artifacts for forest dwellers and their positive aspects have been neglected (Rosenvald and Lõhmus, 2008; Russell et al., 2005; Sebek et al., 2015; Similä et al., 2002), recent studies have indicated that they function as important habitats for grassland plants (Eldegard et al., 2015; Jonason et al., 2014; Peterken and Francis, 1999; Smith

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et al., 2007) and animals (Russell et al., 2005; Sebek et al., 2015; Spitzer et al., 2008), particularly butterflies (Benes et al., 2006; Berg et al., 2011, 2013; Ibbe et al., 2011; Ohwaki et al., 2018; van Halder et al., 2008; Viljur and Teder, 2016). Although the vegetation of forest clear-cuts is temporary and bound to disappear during several or a decade of years at a stand scale (Inoue, 2003; Viljur and Teder, 2016), it will occupy a steady proportion of areas within the forest landscapes if production forest landscapes are regularly managed. In the face of severe grassland decline, recent accumulated knowledge on the flora and fauna of the modern open biotopes suggests that clear-cuts may be an important alternative to support grassland flora and fauna.

Biological communities in temporary clear-cuts are influenced by past land use and time since wood clearing. Recent studies on plants and butterflies in clear-cuts showed that a suitable condition for grassland plants and butterflies lasts only around 10 years (Fartmann et al., 2013; Kobayashi et al., 2010; Viljur and Teder, 2016) and that the clear-cuts with a grassland land use history harbor higher richness of plants and butterflies than those with a forest land use history (Blixt et al., 2015; Ibbe et al., 2011; Jonason et al., 2014). Most of the previous studies surveyed a single taxon (with an exception of one study: Yamaura et al., 2012b), and there is paucity of studies that directly compared flora and fauna between grasslands and clear-cuts (Berg et al., 2011; Yamaura et al., 2012b). Because butterfly communities are strongly affected by resource plant communities, usefulness of clear-cuts in conserving both plants and butterflies should be evaluated simultaneously. In particular, investigation of both plants and butterflies with a focus on endangered species and butterfly resources (nectaring flowers and host plants) will provide a deeper insight into the evaluation of the value of clear-cuts as alternative grassland habitats than the studies on a single taxon.

In Japan, grasslands have been severely declining due to abandonment and conversion into other land use types (e.g., coniferous plantation) since the early 20th century (Ogura, 2012; Ushimaru et al., 2018). Because of these changes, many grassland species are now endangered in Japan (Nakamura, 2011; Takahashi and Naito, 1997). Meanwhile, plantation forests currently occupy 27.2% of the national land surface and 40.9% of the forested areas (Forestry Agency Japan, 2016). Even though many of the mature planted forests remain unharvested due to the decline in forestry as an industry in Japan, forestry is still relatively active in some areas of Japan, e.g., our study area, and the areas of clear-cuts are expected to increase due to global wood demand in the future (Yamaura et al., 2012a). Yet, the lack of comparative studies between grasslands and clear-cuts makes it difficult to assess the role of clear-cuts for maintaining grassland flora and fauna. Considering the large areas of plantation forests and the severe situation of grassland species in Japan, such comparative studies are greatly needed.

In this study, we investigated plants and butterflies in clear-cuts and semi-natural grasslands in central Japan. We selected plants and butterflies as the study materials because butterflies are considered to be among the most sensitive taxa to recent land use changes, thus their conservation is urgently required (Nakamura, 2011; Thomas, 2005), whereas plants are the basic resources for herbivorous insects and shape their community structures (Uchida and Ushimaru, 2014). Grassland plants also include many endangered species (Takahashi and Naito, 1997). We addressed the following questions: (1) To what extent do clear-cuts support plants, butterflies, and butterfly resources found in grasslands? (2) How many endangered species are observed in clear-cuts, and does the importance of clear-cuts for sustaining endangered species differ between plants and butterflies? and (3) What are the important factors that affect species richness of plants and butterflies in both clear-cuts and grasslands? Plant communities in clear-cuts are mainly explained by remnant populations, whereas immigrants from nearby grasslands and soil seed banks are less important (Jonason et al., 2014). On the contrary, butterflies are mobile and sometimes utilize apparently hostile matrix, and thus are expected to immigrate into clear-cuts relatively easily (Dennis, 2004; Dennis and Hardy, 2007; Viljur and Teder, 2018). As a result, immigration of plants into clear-cuts is less likely compared to butterflies; therefore, plant communities would be more strongly affected by local processes and biotope types than butterfly communities. Therefore, we predicted that the proportion of endangered species that utilize clear-cuts was higher for butterflies than for plants, and that differences in species composition between clear-cuts and grasslands are more pronounced for plants than for butterflies.

2. Materials and methods

2.1. Study site

Study sites were located on the northern foot of Mt. Fuji (138°35′59″–54′26″ E, 35°23′44″–29′31″ N; 30 km from the east to the

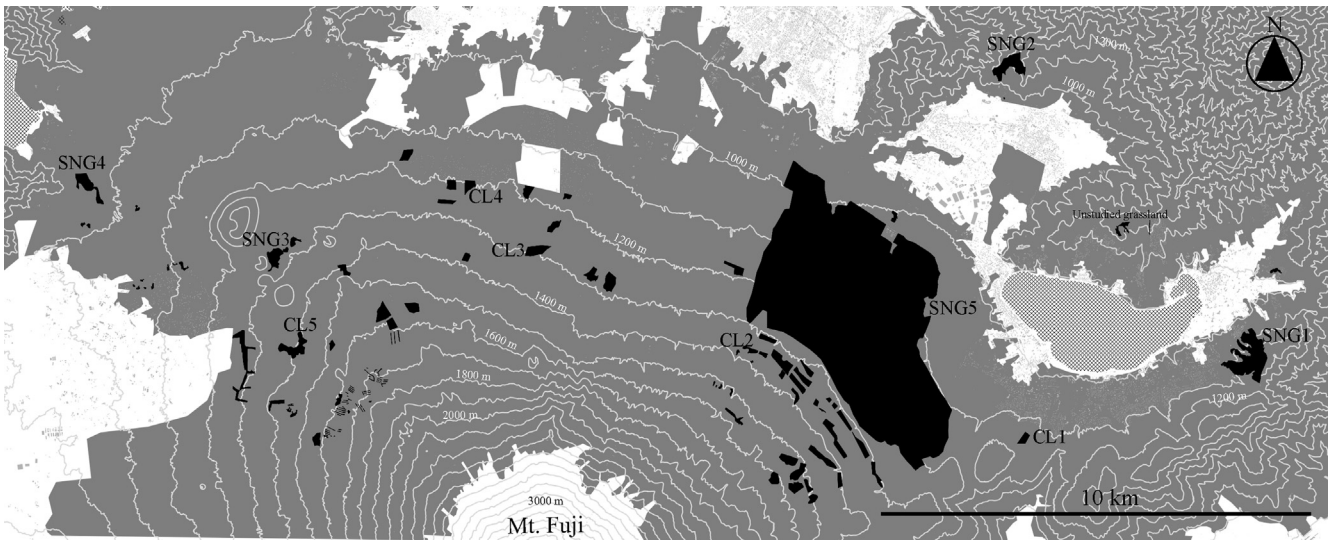

Fig. 1. Map of the study area with contour lines. Grasslands and clear-cuts are shown in black polygons and each study site is indicated. Forested areas (including both natural and plantation forests), buildings and houses, and lakes are shown in dark grey, pale grey, and mesh. Empty areas are non-forested areas, i.e., residential areas, golf courses, agricultural lands, and an alpine zone. Here, only clear-cuts ranging from two to ten years are shown. Note that only six grasslands (G1–5 and the unstudied one) exist in this area.