Agriculture, Ecosystems and Environment 249 (2017) 31–37

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

Influence of farmland abandonment on the species composition of wetland ground beetles in Kushiro, Japan

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ARTICLE INFO

Keywords:
Agricultural landscape
Biodiversity
Carabid
Fen
Passive restoration
Re-wilding

ABSTRACT

Depopulation trends in many developed regions are resulting in an increase in areas of abandoned farmland, which could provide an alternative habitat for species endangered by past conversion of wetlands for agriculture. Additionally, various spatial and temporal factors (landscape structure, local habitat quality, and abandonment age) could influence species composition in abandoned farmland. In this study, we explored the spatio-temporal effects of land abandonment on the species composition of wetland ground beetles (Coleoptera: Carabidae) to examine whether abandoned farmland can contribute to conserve wetland species' habitats. We first compared ground beetle assemblages among four land uses (grassland, wetland, and newly and previously abandoned farmland) in the Kushiro region, eastern Hokkaido, Japan. We then examined the factors influencing differences in wetland species composition between abandoned farmland and wetland. We found that the composition of wetland species in abandoned farmland was more similar to that of wetland than that of grassland. Our results also showed that soil moisture in abandoned farmland was positively related to the land abandonment age and that differences in wetland species composition between abandoned farmland and wetland were negatively related to both soil moisture and surrounding wetland area. Our findings suggest that abandoned farmland can serve as an alternative habitat for wetland ground beetles. Maintaining a high level of soil moisture in abandoned farmland and conserving the surrounding wetland could be an effective strategy for restoring natural habitats for these species.

1. Introduction

Many developed countries are undergoing a period of transition from over-population to under-population (United Nations, 2016), and this social change has led to drastic alterations in arable land use, whereby decreasing population density is accelerating farmland abandonment (Benayas et al., 2007). Abandoned farmland can provide an alternative habitat for wildlife that has experienced range contractions due to the past expansion of arable land (Navarro and Pereira, 2015). For example, several studies suggest that abandoned farmland has contributed to the range expansion of forest-dwelling birds or large mammals in Europe (Boitani and Linnell, 2015; Sirami et al., 2008). Overall, releasing land for the natural recovery of vegetation is less costly than active restoration of degraded habitats (e.g., Barral et al., 2015; Morrison and Lindell, 2011). In addition, the conflict between conservation and development may be smaller for abandoned farmland than for other land uses. Therefore, the natural recovery of vegetation in abandoned farmland may provide a practical option for restoring wildlife habitats.

The first step toward effective restoration of abandoned farmland is to identify the factors regulating habitat conditions for target species (Sandom et al., 2013). As characterized by the vegetation or soil conditions, local habitat quality is expected to act as a primary environmental filter influencing the successful colonization of abandoned farmland (e.g., Brambilla et al., 2010), but it could also change with vegetation succession (Shoo et al., 2016). While, with regard to the dispersal ability of species and colonization processes (e.g. Hanski, 1999), the landscape structure, such as the amount of surrounding source habitat or the distance between the abandoned farmland and the source habitat, may determine the immigration potential of organisms into abandoned farmland. The importance of landscape structure can vary according to the dispersal capability of the target species (e.g., Fensham et al., 2016), and both landscape structure and dispersal capacity affect the time required for successful colonization (i.e.,

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http://dx.doi.org/10.1016/j.agee.2017.07.027
Received 29 July 2016; Received in revised form 19 July 2017; Accepted 20 July 2017

colonization credit; Piqueray et al., 2011). Although many studies have separately explored the effects of spatial (amount of and distance from the source habitat) and temporal (change in habitat quality) factors, few studies to date have comprehensively addressed spatio-temporal effects (Fensham et al., 2016). Although successful restoration requires colonization of individual species at the beginning stage, and also population persistence in a long time frame, in this study, we focus on the effect of these environments on the colonization of abandoned farmland by various species.

Wetland ecosystems are among ecosystems most threatened by cultivation and urbanization activities (Fujita et al., 2009; Gardner et al., 2015). Indeed, the global loss of wetland continues even today (Talberth and Gray, 2012), and the conservation and restoration of wetland habitats are of high priority because many specialist species inhabit wetland environments and most of these species are threatened (Ramsar Convention Secretariat, 2013; Zedler and Kercher, 2005). Farmland abandonment often occurs in land with low productive potential or poor drainage (high soil water potential). In addition, Kusumoto et al. (2005) demonstrated that wetland plant species can regenerate in abandoned farmland with high soil water potential. Therefore, the utilization of abandoned farmland with poor drainage conditions may be a practical option for restoring wetland ecosystems.

In the present study, we explored the spatio-temporal effects of land abandonment on the species composition of wetland ground beetles (Coleoptera: Carabidae) to examine whether abandoned farmland can contribute to wetland species conservation. We investigated 1) how the species composition of ground beetles is influenced by farmland abandonment and 2) the environmental factors that are involved. Ground beetles were selected for the study because they comprise diverse taxa with wide distributions (e.g., Koivula, 2011), are sensitive to environmental changes and have been used as a biological indicator in various landscapes (e.g., Rainio and Niemelä, 2003).

2. Materials and methods

2.1. Study area

The study was conducted in the Kushiro region, Hokkaido, northern Japan (Fig. 1). The annual mean temperature and precipitation in the area are 6.3 °C (ranging from 5.0 to 7.7 °C) and 1057.0 mm (from 704.5 to 1577.0 mm), respectively (data from 1980 to 2015, provided by Kushiro Climatological Observatory, located within the study area). The Kushiro Wetland, the largest peat wetland in Japan, covers 19,357 ha of this region, and more than 80% of the wetland consists of fens dominated by reed, sedge, and shrubs. Since the 19th century, the Kushiro Wetland has been converted to urban land use and grassland, and 30% of the wetland was lost during the last five decades (from 28,135 ha in 1947 to 19,357 ha in the 2000s; Ministry of the Environment, 2015). However, in the 21 st century, the population of the Kushiro sub-prefecture has been declining, and the abandoned farmland has been increasing (from 758 ha in 2000 to 1691 ha in 2015; Policy Department of Hokkaido Prefecture, 2015).

For this study, we selected 37 survey sites belonging to four land uses in the Kushiro region (Fig. 1): 14 newly abandoned farmland (abandoned after the 1990s), 11 previously abandoned farmland (abandoned before the 1980s), 6 grassland (with mowed twice per year), and 6 remnant wetland (fen) sites. All survey sites in abandoned farmland areas had been wetland areas in the 1920s and were converted to grassland areas and later abandoned. The survey sites in grassland and wetland areas were selected as a reference for land use in arable land and pristine vegetation, respectively. All the survey sites were located more than 500 m apart from each other. Because no accurate data for abandonment age was available, we estimated the age of abandonment by interviewing land owners or neighbors around each survey site, and we classed the duration of abandonment into two categories: after the 1990s and before the 1980s. The dominant plant species were *Phalaris arundinacea* in both newly and previously abandoned farmland sites, *Phleum pratense* in the grassland sites, and *Phragmites australis* and *Calamagrostis langsdorffii* in the remnant wetland sites.

2.2. Ground beetle sampling

To examine the species composition of ground beetles at each survey site, we collected ground beetles using pitfall traps in two periods: early summer (June 19 to July 24) and autumn (August 27 to September 12) 2014. At each survey site, we set 16 pitfall traps placed in a grid of 2 × 8 traps for 2 weeks per period, with each trap located more than 5 m away from any other trap. Then, the grid was placed at a minimum distance of 10 m from the edge of each field. The traps were 95 mm in diameter and 124 mm in depth and contained approximately 50 ml propylene glycol as a preservative. We placed a square veneer plate (120 mm x 120 mm) above each trap to block the accumulation of rainwater. In wetland, we placed the traps on the ground, avoiding puddles, and made four or five small holes at 4 cm below the top of a trap to prevent the overflow of rainwater. The beetles were identified to the species level and categorized into three groups according to the Working Group for Biological Indicator Ground Beetles Database Japan, (2015) and Ueno et al. (1985): wetland species, open-land species, and others (including forest or generalist species). Because the “others” group contained few species and was low in abundance (12 species and 852 individuals, 5.5% of the total abundance), we only used samples of wetland and open-land species in the subsequent analysis. All samples at each survey site were pooled for analysis. For the two survey periods, the average number of undisturbed traps was 31.5, so we normalized the ground beetle abundance based on the number of undisturbed traps at each site and used those abundance data in the analysis.

2.3. Habitat quality and landscape structure

To examine the effect of habitat quality on species composition, we surveyed vegetation density and soil moisture at each survey site in June and August of 2014. At each site, we established 16 survey points, each of which was located near a pitfall trap. We first placed a metal rod vertically at the survey point, and recorded the presence of vegetation touching the rod at 50 cm intervals (0–50 cm, 51–100 cm, 101–150 cm, and 151–200 cm). We summed all the presence/absence data of plant species for each survey point (ranging from 0 to 4) and then averaged the data for the 16 survey points for each survey site. At all 16 survey points at each site, soil moisture was measured at a depth of 15 cm using a soil moisture meter (HydroSense, Campbell Scientific, Inc., Logan, USA). The values of vegetation density and soil moisture measured in June and August were averaged for each survey site.

To examine the effect of landscape structure on the species composition of ground beetles, we made a vector map of the vegetation data, including abandoned farmland, from the latest digital vegetation map (scale of 1: 25,000; Ministry of Environment of Japan, 2004). We confirmed the locations of abandoned farmland through the interviews with farmers or local officers and through our visual observations. We calculated the patch area of abandoned farmland as an indicator of habitat quality (e.g., MacArthur and Wilson, 1967), the amount of wetland area within a 500-m buffer around the survey sites and the nearest distance between abandoned farmland and wetland, a variable that affected the colonization of abandoned farmland by wetland species from the source habitat (e.g., MacArthur and Wilson, 1967; Quesnelle et al., 2015). The size of the buffer size was chosen based on previous studies (e.g. Woodcock et al., 2010). This work was conducted using Quantum GIS version 2.8.2 (QGIS Development Team, 2015).

2.4. Statistical analysis

To assess how species composition is altered by farmland