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Which carabid species (Coleoptera: Carabidae) profit from organic farming after a succession of 15 years?

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ABSTRACT

The changes of the ground beetle assemblages during the 15 years succession after the conversion from conventional to organic farming was investigated in northern Germany, with the aim to find trends for the communities on organically farmed fields. The succession showed that the carabid assemblages developed from typically wide-spread communities on loamy soils to assemblages, which are typical for more sandy soils and open habitats. All nine fields studied had the same direction in their succession. At the beginning, the composition of the assemblages was nearly similar but they developed during the succession into more diverse communities with a greater heterogeneity and changes between years. A detailed analysis of ecological groups revealed that species preferring forest margins disappeared from the fields, whereas species preferring open habitats benefited from the conversion. Some species were able to disperse further into the field centres, some could invade from the field margin to the centres and some newly immigrated during the succession and could also disperse into the field. The conclusion drawn from these results is that, in general, species from open habitats will benefit from organic fields.

1. Introduction

The detrimental effect of modern, industrial-like farming has been a widely-known fact for decades. Society and politicians, therefore, search for sustainable land-use practices which preserve soils and ecosystem functions. Organic farming is regarded as one of the favoured practices to solve problems emerging from modern conventional farming (e.g. Crowder et al., 2010; Hansen, 1996; Rigby and Caceres, 2001). It should provide ecosystem services that under conventional farming in the long-term will be deteriorated and generate high financial costs for the society. Although biodiversity is not specifically named under ecosystem services, its loss is one of the effects of modern conventional farming (e.g. Bengtsson et al., 2005; Hole et al., 2005).

Carabid beetles are one of the groups that are often used to indicate species diversity in agricultural fields (Döring et al., 2003). They are one of the most numerous groups of insects found in agro-ecosystems in the northern hemisphere (Kromp, 1999). In pre-industrial farming, they played an important role as natural pest and weed control agents, and may, therefore, be of further interest for sustainable agriculture.

In the year 2002, after several decades of intensive conventional husbandry, organic farming practices were introduced at Hof Ritzerau. The owner of the farm decided to monitor succession patterns that occurred after the management conversion. In the first investigation after 10 years, no increase in carabid diversity was recorded in regard to the total area (Schröter and Irmler, 2013). However, after this 10-year period, at central parts of the fields that were formerly characterised by an extremely low diversity, an increase in diversity which equaled that of the field margins was revealed. Schröter and Irmler (2013) interpreted this effect to be the reduction of the barrier that exists under conventional farming which results in an isolation of the adjacent communities and, thus, is at least partly responsible for the loss of total biodiversity in the landscape.

The present investigation will focus on the succession effects on different groups of the carabid fauna over a period of 15 years after the conversion from conventional to organic farming. In particular, the following questions should be answered: (1) Is there a directed succession of the field community? (2) Which aim does the succession have? (3) Do all fields have the same succession direction? (4) Which ecological groups of species benefit from organic farming? (5) Which ecological groups suffer under organic farming?

2. Sites and methods

The study site is located in the south-eastern area of Schleswig-Holstein, northern Germany. Climate is moderate with 685.5 mm long-term average of rainfall and 8.1 °C mean yearly temperature. The farm has approximately 183 ha arable land and 40 ha grassland. The total agrarian area is subdivided into nine arable fields. Whereas the

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Table 1
Characterisation of soils, area, and adjacent habitats of investigated fields on Ritzerau Manor.

Field name	Site code	Area (ha)	Sand content (%)	pH	Organic Cont. (%)	Forest margin (m)	Wet grassland margin (m)
Abenrade	App	12.3	66.1 ± 8.2	5.9 ± 0.4	3.6 ± 0.2	741	79
Dachsberg	Dachs	29.6	62.8 ± 6.2	6.0 ± 0.5	3.2 ± 0.5	229	922
Fuchsberg	Fuchs	23.0	65.5 ± 6.0	5.5 ± 0.3	4.0 ± 0.3	748	0
Hellberg	Hell	17.7	61.1 ± 4.9	6.2 ± 0.8	3.3 ± 0.4	0	732
Koppelbusch	Kopp	16.9				190	584
Peperland	Pep	28.8	58.9 ± 7.2	6.2 ± 0.4	3.6 ± 0.2	446	0
Seekamp1	See1	20.6	60.0 ± 6.9	6.5 ± 0.5	3.7 ± 0.4	0	652
Seekamp 2	See2	16.5				0	264
Stutenkoppel	Stut	13.4	58.6 ± 12.7	6.3 ± 0.4	3.9 ± 0.9	0	489

farmland borders forests at its western and northern sides, on the eastern and western borders are wet grassland, and on the south and south-west borders are pastures, conventional fields and fallow. The soil type is sandy loam (Reiss et al., 2008).

Organic farming was introduced stepwise in separate field sections. The periods of conversion were as follows: Conventional period with strictly conventional farming using insecticides, herbicides and fertilizers on the total area in 2001; transitional period between 2002 and 2003 with 47 ha converted in autumn 2002 and an additional 23 ha in autumn 2003; organic period from 2004 to today, with organic farming on the total field area. Additionally to arable land and grassland, the farm comprises 15 ha hedgerows, shrubberies, and field margins (areas changed slightly between years). The conventional crop rotation was winter-wheat, winter-barley and winter-rape. The organic crop rotation contained winter- and summer-wheat, winter-rye, summer-oats, peas and a grass/clover-mixture. The grass/clover-mixture was cut up to three times per year or grazed by sheep after the first cut.

Ground beetles were recorded by pitfall traps over the entire year (Table 1). All traps were located using a GPS and the location remained constant over the years. The crop at the specific location changed between years; however, Andersen and Elton (2000); Irmler (2003); Andersen (2003) showed that field crops had little influence on the composition of the occurrence of carabids. Habitats outside the arable fields were classified as set-aside areas. These areas were moist fallow grassland, sometimes covered by open shrubbery or grassy strips beside farm tracks.

A total of 123 pitfall traps were installed, 96 pitfall traps on arable fields and 27 on set-aside areas for the entire year, except during harvesting and other farming activities in August and September. The traps were installed every year from 2001 to 2004, but only every second year from 2006 to 2016. Pitfall traps were glass jars, 11.0 cm high and 5.7 cm in diameter and were sheltered against rainfall by a transparent plastic 20 × 20 cm cover. Undiluted mono-ethylene glycol was used as preservative. The traps were arranged in a grid over the investigation area and exchanged at monthly intervals.

The distance between the traps and their closest near-natural habitat, the size of the fields, and the set-aside areas were measured using ArcView 3.2 (ESRI Inc., 2000). The distances of pitfall traps to the field margin were classified into the five classes: 0–30 m, > 30–60 m, > 60–120 m, > 120–240 m. Pitfall traps outside the arable fields contributed to class < 0 m.

All ground beetles were determined to species level according to Müller-Motzfeld (2004). Activity densities were standardized as individuals 100 days^{-1} trap^{-1} for most statistical analyses. The change of the carabid assemblages over the 15 years was investigated using the Detrended Correspondence Analysis (DCA). The change of assemblages of the study sites was compared with assemblages of other arable fields distributed across Schleswig-Holstein. For this analysis, the data of 53 arable fields published by Irmler and Gürlich (2004) were used (see also Irmler, 2003). Carabid species were characterised by ecological groups and environmental indication values using the results of Irmler and Gürlich (2004), who grouped carabid species of Schleswig-Holstein using investigations with carabids and environmental data at 259 locations. Irmler and Gürlich (2004) differentiated 30 habitat types. Here, only the ecological groups indicating forests, open dry areas, and open moist areas were used. The number of species of each ecological group was correlated with the number of years passed since the beginning of the investigations in 2001. Correlations were performed using the specific indication values for tree coverage and soil moisture in the same way. The weighted mean of distance from field margin and the amount in pitfall traps was calculated for each species and each year. The change of this value was correlated as well with the number of years since 2001. As all data showed normal distribution, the Pearson correlation was used. Statistical analyses were performed using Statistica 6.1 (StatSoft, 2004) or PAST 2.04 (Hammer et al., 2012).

3. Results

3.1. Succession of assemblages

In the first step, the carabid assemblages of the arable fields on Hof Ritzerau were compared with assemblages distributed across Schleswig-Holstein under different soil conditions and under different farming practices (Fig. 1). The DCA separates the arable fields with an eigenvalue of 0.76. According to Ter Braak (1987) an eigenvalue of 0.5 is sufficient to separate assemblages significantly. Overall, conventionally farmed fields were only partially separated from organically farmed fields. The separation along the first axis is a mixture between farming practices and soil conditions, as can be seen by the separation of fields with more than 80% sand content in the soil. Nevertheless, the succession direction of the Ritzerau assemblages point to field assemblages with predominantly organic farming and sandy, nutrient-poor soil conditions.

In the next step, the succession among the Ritzerau assemblages was tested using the single years of investigation (Fig. 2). The eigenvalue of the DCA for the fields on Ritzerau farm was only 0.49, which is at the limit of a significant separation of assemblages, meaning that the composition of the assemblages is very similar. At the beginning of the investigation under conventional farming, all fields had nearly identical compositions of the carabid assemblages. The succession on all fields points in one direction, which means that the overall direction under organic farming resembles among the fields.

However, assemblages of single fields varied along axis 2. After 15 years, the similarity of the assemblages among the fields were lower than at the beginning. These changes were observed across the years of the investigation.

3.2. Succession of groups with similar ecological preferences

The correlation between the species richness of the three groups analysed and the number of years after conversion revealed a loss of species with an affinity to woody sites (Fig. 3). Whereas at the beginning of the succession approximately 17 species defined as wood-dwelling species by Irmler and Gürlich (2004) were present, only