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Organic cultivation reduces barrier effect of arable fields on species diversity

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ABSTRACT

Spatial and temporal changes in ground beetle populations of a northern German farm during the conversion from conventional to organic methods were studied between 2001 and 2007. The conversion of the total arable area was partially performed beginning in autumn 2001 and completed in spring 2004. During the conventional period, species richness and diversity of ground beetles were negatively correlated with distance from field margin toward field centre, reaching a minimum at 60–240 m. Species diversity increased to match levels found in set-aside areas outside of arable fields 4 years after conversion. Species richness, however, remained poor at the centres of arable fields. *Pterostichus melanarius* was the most abundant species, averaging more than 50% dominance. At the beginning of organic farming in 2002, the abundance of nine species typical for arable fields and grassland increased, whereas the dominance of *P. melanarius* decreased. Species affected positively by organic farming were found in the conventional period outside the arable fields in high numbers.

1. Introduction

Ground beetles are one of the most numerous groups of insects found in agroecosystems in the northern hemisphere (Kromp, 1999). The low dispersal ability of carabids prevents rapid recuperation of losses in arable fields within a farming year (Thomas et al., 1991). Ploughing has negative effects on the survival of most carabids, particularly in monocultures with repeated tillage cycles (Holland and Reynolds, 2003; Thorbek and Bilde, 2004). Many species hibernate in adjacent habitats such as hedgerows and grassy strips beside farm tracks or ditches. These set-aside areas support the recolonization of fields, act as corridors for dispersal, offer breeding refuge, and supply food (Holland and Luff, 2000). Today, these habitats are rare because land consolidation engineering 40 years ago combined small fields to create larger fields that are more efficiently cultivated. Investigations have shown that increasing distance to field boundaries diminished species richness (Holland et al., 1999; Collins et al., 2002).

The state of Schleswig–Holstein in northern Germany is dominated by farming that in 2007 covered 74% of total land area; the national average was 55%. Cereals were cultivated on 54% of the arable land, while 45% was maintained as permanent grassland (Statistisches Landesamt, 2010). Only 2.9% of the farmers managed 3.4% of the farmland area organically. In the year 2002 at Hof Ritzerau, after several decades of intensive conventional husbandry, organic farming methods were introduced to the first section of arable land. The owner of the farm decided to monitor successional patterns that occurred during management conversion. The purpose of this study is to answer the following questions: (1) How does the species composition of ground beetles change when, after many years of conventional farming, organic farming methods are established? (2) What changes in species richness or species diversity result in the conversion to organic farming? (3) How will recolonization of arable fields by ground beetles proceed after the establishment of organic farming?

2. Materials and methods

The study site is located in the south-eastern area of Schleswig–Holstein, in 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. At its western and northern sides, the farmland borders a forest, and on its eastern and western sides borders grasslands and a creek. In the south, pastures and a conventional field border the farm, and in the south-west, a fallow is adjacent to the arable land. 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 in 2001/02 with strictly conventional farming using insecticides, herbicides and fertilisers on the total area; transitional period between 2002/03 and 2003/04 with 47 ha converted in autumn 2002 and an additional 23 ha in autumn 2003; organic period from 2005/06 and 2007/08, with organic farming on the total

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Table 1
Number, location and distance from field margin of pitfall traps; conv./organic: conventional/organic management.

Year	2001/02	2002/03	2003/04	2005/06	2007/08
Total	163	167	167	124	124
Field: conv./organic	133/–	95/44	88/51	–/98	–/98
Distance classes [m]					
<0[a]	30	28	28	26	26
30	27	34	34	18	16
60	49	48	48	38	39
120	33	33	33	24	25
240	24	24	24	18	18

[a] Traps located in set-aside areas outside the arable fields.

field area. The farm's 183 ha arable land is divided into ca. 169 ha crop area, ca. 5 ha with hedgerows or shrubberies, and ca. 9 ha greenbelts or fallows as supported by European Union directives. 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 mown up to thrice a year or grazed by sheep after the first cut. The 40 ha habitats outside the arable fields were classified as set-aside and comprised moist fallow grassland, sometimes covered by open shrubbery, or grassy strips beside farm tracks.

Ground beetles were sampled by pitfall trapping over the whole year (Table 1), traps being localised using a DGPS tool (husky fex21, Husky Technologies Ltd., England) and the locations remained the same over the years. The traps were 11.0 cm high and 5.7 cm in diameter and covered against rainfall by a transparent plastic cover of 20 cm × 20 cm. As preservative, undiluted monoethylene glycol was used. The traps were arranged in a grid over the investigation site and they were changed regularly in monthly intervals. The distance between the traps and their closest set-aside 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 five classes according to data given in Table 1. Pitfall traps outside the arable fields contributed to class <0 m.

All ground beetles were determined at species level according to Müller-Motzfeld (2004). Activity densities were standardised as individuals 100 d^{-1} $trap^{-1}$ for most statistical analysis. Shannon index H_S was used to calculate species diversity. Non-parametric Kruskal–Wallis-ANOVA was used to compare variables that were measured in independent samples and the Friedman-ANOVA was used for dependent samples. The Mann–Whitney *U*-test was used to analyse differences in activity densities, species richness, species diversity between arable fields and set-aside, and conventional vs. organic farming. The rarefaction-method was performed to compare species richness over years with different trap numbers (sample rarefaction), and to analyse the effect of yearly activity density compared to species richness (individual rarefaction). For the individual rarefaction, the number of individuals was limited to 1000 specimens, using the same level for all years and distance classes. The abundance on organic vs. conventional fields of the 19 most frequent species was tested by the *U*-test. Statistical analyses were performed using Statistica 6.1 (StatSoft, 2004) or PAST 2.15 (Hammer et al., 2001).

3. Results

3.1. Species richness and diversity

The yearly number of carabids decreased during the investigation (Table 2). Inside both set-aside habitats and arable fields, the range was between 31.1 and 54.5 ind. 100 d^{-1} $trap^{-1}$ and 37.2 and 101.0 ind. 100 d^{-1} $trap^{-1}$, respectively. Whereas activity density in the set-aside habitats showed no significant differences between the 5 years (Friedman-ANOVA with $p = 0.26$, $Chi^2 = 5.29$, df = 4, coeff. of concordance = 0.51, average rank = 0.01), the differences between highest values in 2001/02 and 2003/04 and lowest values in 2007/08 on the arable fields were significant (Friedman-ANOVA with $p < 0.001$, $Chi^2 = 125.81$, df = 4, coeff. of concordance = 0.32, average rank = 0.32).

Overall, 130 carabid species were recorded in the 5 years investigated, with most carabid species in the first year (Table 2). Inside the set-aside habitat, no significant differences were found between the yearly averages of species richness (Fig. 1). On arable fields, species richness varied significantly between years. In all years, the set-aside habitats had higher species richness than arable fields (2001/02: $U = 749.0$ with $p < 0.001$; 2002/03: $U = 1182.5$ with $p < 0.01$; 2003/04: $U = 1011.0$ with $p < 0.001$; 2005/06: $U = 891.5$ with $p < 0.05$; 2007/08: $U = 249.5$ with $p < 0.001$).

According to the results of the rarefaction analyses, species richness in the set-aside habitats ranged between 59.9 ± 3.0 species 1000 $ind.^{-1}$ in 2002/03 and 69.5 ± 2.1 species 1000 $ind.^{-1}$ in 2001/02 (Fig. 2). In the agrarian area, rarefaction species richness was low in the conventional and transitional period, ranging between 34.1 ± 2.9 and 36.8 ± 2.8 species 1000 $ind.^{-1}$, and high in the organic period, when it varied between 40.5 ± 2.5 species 1000 $ind.^{-1}$ in 2005/06 and 44.1 ± 2.9 species 1000 $ind.^{-1}$ in 2007/08.

The H_S-level in set-aside habitats varied between 2.17 and 2.46 with no significant difference between the years. The Shannon diversity indices on the agrarian farmland were lower, in particular, in years with conventional and transitional management. During the conventional and transitional period, the Shannon indices ranged between 1.51 and 1.70 without significant difference. In the organic period, the H_S-index on the agrarian farmland increased up to 2.10 and 2.18. The difference between the organic and the conventional/transitional period was significant (*U*-test: $U = 34{,}093$, $Z = 5.68$, $p < 0.001$). In four of the five years, the species diversity of the crop area was characterised by lower values than the set-aside area (2001/02: $U = 301.5$, $Z = 7.25$ with $p < 0.001$; 2002/03: $U = 586.5$, $Z = 5.82$ with $p < 0.01$; 2003/04: $U = 585.5$, $Z = 5.82$ with $p < 0.001$; 2005/06: $U = 1043.0$, $Z = 1.21$ with $p = 0.22$; 2007/08: $U = 621.0$, $Z = 3.84$ with $p < 0.001$).

The individual rarefaction species richness changed with the distance from the field margin. In the 30 m-class, values ranged between 39.8 ± 2.7 and 42.4 ± 2.8 species 1000 $ind.^{-1}$ between the years 2001/02 and 2005/06. In the year 2007/08, after the conversion ended, species richness increased distinctly to 54.7 ± 1.6 species 1000 $ind.^{-1}$. In the 60 m-class, all years with conventional and transitional farming were characterised by lower values (between 32.1 ± 2.7 and 35.7 ± 2.7 species 1000 $ind.^{-1}$) than years with organic farming (2005/06: 40.6 ± 2.4, 2007/08: 40.0 ± 2.5

Table 2
Number of species and individuals sampled under conventional (c), conventional and organic (c-o) or organic (o) farming; s.d.: standard deviation.

Year	2001/02	2002/03	2003/04	2005/06	2007/08
Species [no.]	108	101	99	98	98
Individuals [no.]	30,052	48,991	25,640	22,581	13,777
Activity density [$trap^{-1}$ d^{-1} ± s.d.]	0.69 ± 0.35	1.02 ± 0.55	0.69 ± 0.39	1.02 ± 0.73	0.42 ± 0.27
Trap days [mean ± s.d.]	275.6 ± 44.8	290.6 ± 34.3	226.2 ± 42.9	189.3 ± 57.4	247.9 ± 63.4
Management	c	c-o	c-o	o	o