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Composition and dynamics of the invertebrate fauna in three agricultural ecosystems in Schleswig-Holstein

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Summary

Three different land use systems, i.e. agricultural field, dry pasture and wet grassland, were investigated between 1988 and 1990 in order to document the differences in the composition and the biomass of the invertebrates of soil and low vegetation. The aim was to find out why there is a decrease of overall biodiversity and of the food supply for birds in the course of homogenizing the land use in the agrarian landscape. The investigation was performed using sampling methods that took area-related results into consideration. The results clearly showed that many invertebrate groups exhibited losses in species richness from the agricultural field to grassland systems combined with a decrease of biomass, in particular, of the soil floor fauna. However, some invertebrate groups, i.e. Lumbricidae and Carabidae, still have high species densities and/or high biomasses on agricultural fields. The seasonal dynamics of biomasses vary between the three land use systems. It can be derived from the site-specific composition of invertebrate groups and the seasonal dynamics that a mosaic of different land use systems provides the best conditions for maintaining a high biodiversity and continuous food supply for large predatory animals.

Keywords: agrarian landscape, biodiversity, species density, seasonal dynamics

Zusammenfassung

Zusammensetzung und Dynamik der Invertebratenfauna in drei landwirtschaftlich genutzten Ökosystemen in Schleswig-Holstein

In den Jahren von 1989 bis 1990 wurden drei Landnutzungssysteme, ein Acker, eine trocken Weide und ein feuchtes Grünland, untersucht, um die Unterschiede in der Zusammensetzung und Biomasse von Invertebraten des Bodens und der niederen Vegetationsschicht zu erfassen. Das Ziel war, Ursachen für den allgemeinen Rückgang der Biodiversität und des Nahrungsangebots für Vögel in einer homogenisierenden Landnutzung in der Agrarlandschaft zu finden. Für die Untersuchung wurden Erfassungsmethoden angewandt, die eine flächenmäßige Beurteilung der Ergebnisse zulassen. Die Ergebnisse zeigen deutlich, dass viele Gruppen der Invertebraten einen Verlust der Artenzahl und einen Rückgang an Biomasse vom Acker zum Grünland aufweisen. Dieser Verlust ist insbesondere bei der Fauna der Bodenoberfläche nachzuweisen. Allerdings besitzen einige Invertebratengruppen, z.B. die Regenwürmer und Laufkäfer, hohe Artendichten und/oder Biomassen auf dem Acker. Die saisonale Dynamik unterscheidet sich ebenso zwischen den drei Landnutzungssystemen. Aus der standortspezifischen Zusammensetzung der Invertebratengruppen und der saisonale Dynamik läßt sich ableiten, dass ein Mosaik verschiedener Landnutzungssysteme die besten Voraussetzungen bietet, um eine hohe Biodiversität und ein beständiges, ausreichendes Nahrungsangebot für größere Räuber zu gewährleisten.

Schlüsselwörter: Agrarlandschaft, Biodiversität, Artendichte, Jahresdynamik

Introduction

In northern Germany, a change in land use has taken place over the past decades which resulted in profound changes of the fauna in the agriculturally-dominated landscape. According to NITSCH et al. (2009), the loss of permanent grassland in Schleswig-Holstein has increased between 2.5 % and 7.5 % per year between 2005 and 2008 and, thus, was highest of all German states. On the other hand, the percentage of area for maize production has increased more than 200 % between 1996 and 2010. As this change in agricultural use cannot be without influence on ecological effects in the agrarian landscape, fundamental studies are needed regarding different land use systems. Many birds and other faunal groups depend on specific amounts of food supply and a mosaic of requisites for feeding, breeding and growing which change habitats. Unfortunately, most studies concerning invertebrate dynamics and biomasses are too old to give sufficient answers to these questions, or were performed using inadequate, semi-quantitative sampling methods.

The present data were surveyed in a long-term ecosystem research in the Bornhöved Lake District (FRÄNZLE et al. 2008), but have never been published. Although the data originated from 1988 to 1990, they may represent the possible changes that are associated with the change from grassland to agricultural fields. The following questions should be answered: 1) How does the invertebrate biomass change from agricultural field to different types of grassland? 2) Which animal groups contribute most to the total biomass? 3) How do the dynamics change between seasons?

Sites and methods

The study was executed in the Bornhöved Lake district, approximately 23 km south of Kiel near Lake Belau (coordinates: 54°05.35'N, 10°14.26'E to 54°05.36'N, 10°14.34'E). The agrarian field was situated on a hilltop approximately 42 m above NN, the pasture on the hillslope and the wet grassland near the Lake Belau at approximately 33 m above NN. The soils were fine to coarse sand on the top and peaty near the lake. More information can be found in BLUME et al. (2008). Corn (1988 and 1989) and oat (1990) were planted on the agrarian field.. The pasture and the wet grassland were grazed by approximately 2 cattle per ha.

The study lasted from mid-May 1988 to December 1990. Three types of samples were taken at monthly intervals: from 0.1 m^2 frame: (1) vegetation by using a suction trap covered by a fine-meshed net of approximately 0.5 m height in the two grassland types, (2) floor litter layer at all three sites, and (3) soil cores up to 10 cm depth from a 0.04 m^2 frame. Four replicates were sampled at each site and on each sampling date. The litter and the soil samples were transferred to a MacFadyen Extractor to gain the fauna by heat extraction. The heat extraction lasted 10 days, starting at 20°C and ending at 65°C with a daily increase of 5 °C. The fresh biomass was determined using a balance of 0.1 mg accuracy. Both the calculation of the meso-fauna biomass and of the dry weight is described in IRMLER (1995).

Statistical analyses were performed using the program PAST (HAMMER 2016). Differences between the sites were tested using a Kruskal-Wallis ANOVA with subsequent Bonferroni corrected pairwise comparisons. If only two sites were available, t-test or U-test was used.

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Results

Species composition

The species richness and composition of the animal groups that could be identified to species level differed strongly between the three sites and the groups (Table 1). Regarding Collembola, Staphylinidae, Carabidae, and Araneae, 36, 26, 8, 10 species were found on the agricultural field, 45, 35, 3, 24 species were found on the dry pasture, and 46, 47, 7, 41 species were found on the wet grassland, respectively. The species density of Collembola on 0.1 m^{-2} was significantly highest on the dry pasture, with 40 species, and lowest on the agricultural field, with 29.8 species. Mean species density of both Staphylinidae and Araneae were also significantly lowest on the agricultural field, with 14.5 species and 6.3 species, respectively, and highest on the wet grassland. Only Carabidae showed no significant differences between the sites. Overall, total species density was significantly lowest on the agricultural field and highest on the wet grassland.

Concerning the species composition, Collembolan species showed small differences between the sites. *Cryptopygus thermophilus* were significantly more dominant on the agricultural field, *Lepidocyrtus cyaneus* on the dry pasture and *L. lanuginosus* on the wet grassland. The other animal groups exhibited stronger differences between the sites because several species were restricted to one of the sites, e.g. *Quedius semiaeneus* (Staphylinidae), *Pterostichus diligens* (Carabidae) and *Gyngylidiellum vivum* (Araneae) to the wet grassland. Regarding Staphylinidae, only *Oxypoda sericea* dominated on the agricultural field and the dry pasture, but were found also in the wet grassland. Four species were restricted to the dry pasture and the wet grassland; eight species were restricted to the wet grassland only. In contrast to the other groups, Carabidae had three species that were restricted to the arable field. Besides the dominant spider *Erigone atra*, two further species were found more frequently on the arable field and the dry pasture, but four in the wet grassland. In addition, eight species were restricted to the wet grassland, but no species to the agricultural field or the dry pasture.

Comparison of biomasses

The results for abundance and biomass are listed in table 1. The highest biomass was determined in the wet grassland with a yearly average of 13.2 ± 5.1 g m^{-2}, intermediate in the dry grassland with 4.4 ± 2.7 g m^{-2} and lowest in the agrarian field with 1.1 ± 0.5 g m^{-2}. The differences are significant using a Kruskal-Wallis ANOVA with $p = 0.03$ ($F = 18.75$, $df = 2.66$). In the agrarian field, Collembola were most frequent, but Diptera and Lumbricidae were the groups with the highest biomass. Nevertheless, there Collembola also reached high biomasses of 0.15 ± 0.05 g/m^2.

Table 1: Species richness and dominance of frequent species in the three investigated sites and results of Kruskall Wallis ANOVA; significant differences between sites with Bonferroni correction and were marked by different exponents.

	Agricultural field		Dry pasture		Wet grassland		F	p
	%	S.d.	%	S.d.	%	S.d.		
Collembola/species richness	[a] 29.8	0.5	[c] 40.0	0.0	[b] 33.8	1.7	44.8	<0.01
Cryptopygus thermophilus	[a] 59.7	10.3	[b] 0.2	0.1	[b] 1.4	0.6	7.8	0.02
Isotomurus palustris	25.2	14.4	21.6	1.1	36.6	3.5	4.5	0.06
Isotoma tigrina	5.1	2.7	.	.	0.7	0.3		
Hypogastrura socialis	3.9	2.9	0.1	<0.1	+			
Isotoma notabilis	[a] 1.1	0.5	[b] 10.1	2.0	[b] 6.0	0.5	7.8	0.02
Brachystomella parvula	1.0	0.4	4.3	0.5	0.1	<0.1		
Entomobrya nivalis	0.9	0.4	+		+			
Isotoma viridis	[a] 0.9	0.2	[c] 15.2	2.2	[b] 2.4	0.6	7.8	0.02
Lepidocyrtus cyaneus	[a] 0.8	0.5	[b] 30.0	1.2	[a] 0.6	0.3	4.4	0.01
Folsomia fimetaria	0.3	0.2	1.6	0.2	0.1	0.1		
Onychiurus ssp.	+		3.7	0.1	9.0	3.2		
Sminthurus viridis	0.1		3.4	0.6	0.4	0.2		
Sminthurinus aureus	0.1		3.0	0.1	0.9	0.7		
Lepidocyrtus lanuginosus	[a] 0.1	0.1	[a] 2.8	0.0	[b] 32.3	3.1	7.2	0.02
Isotoma violacea	+		2.0	0.3	5.0	1.1		
Tomocerus minor	.	.	0.1	0.1	3.3	0.7		
Staphylinidae/species richness	[a] 14.5	2.1	[b] 25.5	2.1	[b] 27.5	1.3	57.6	<0.01
Oxypoda sericea	[b] 34.6	5.5	[c] 35.3	3.3	[a] 0.4	0.8	7.8	0.02
Amischa analis	[a] 23.8	3.8	[c] 79.6	38.0	[b] 20.1	6.9	7.8	0.02
Atheta fungi	[a] 14.1	4.2	[a] 11.7	7.3	[b] 12.4	1.6	6.6	0.04
Oligota pusillima	4.5	2.9	2.8	2.2	.	.		
Aloconota gregaria	3.9	3.1	.	.	0.5	0.5		
Gabrius subnigritulus	[a] 1.7	1.2	[a] 2.9	0.5	[b] 5.8	1.2	7.5	0.02
Oxypoda brachyptera	1.6	1.9	.	.	0.2	0.3		
Anotylus rugosus	1.4	1.0	.	.	5.0	2.2		
Liogluta alpestris	1.5	1.0	3.0	1.2	0.5	0.6		
Xantholinus linearis	0.5	0.9	8.2	2.4	.	.		
Tachyporus hypnorum	[a] 1.1	1.2	[b] 7.6	1.6	[a] 2.5	1.6	6.4	0.04
Ousipalia caesula	0.5	0.9	1.8	1.1	.	.		
Tachyporus nitidulus	.	.	2.9	0.5	.	.		
Gabrius breviventer	.	.	2.3	1.4	2.2	0.8		
Atheta orbata	.	.	1.7	0.6	0.6	1.3		
Philonthus cognatus	.	.	1.7	0.6	0.6	0.8		
Tachinus corticinus	0.3	0.7	1.7	0.6	0.2	0.3		
Quedius semiaeneus	.	.	.	.	14.0	4.6		
Atheta elongatula	.	.	.	.	9.1	3.4		
Atheta volans	.	.	.	.	4.2	1.9		
Stenus cicindeloides	.	.	.	.	4.0	1.8		

	Agricultural field		Dry pasture		Wet grass-land		F	p
	%	S.d.	%	S.d.	%	S.d.		
Quedius fuliginosus	.	.	.	.	2.5	1.5		
Stenus juno	.	.	.	.	2.4	1.5		
Stenus clavicornis	.	.	.	.	1.7	0.7		
Stenus similis	.	.	.	.	1.5	0.6		
Carabidae/species richness	3.3	1.0	3.0	0.0	4.8	1.5	1.7	0.2
Bembidion lampros	41.7	12.6	.	.	.	.		
Dischyrius globosus	13.3	16.3	.	.	4.7	6.7		
Trechus quadristriatus	21.7	31.4	.	.	.	.		
Bembidion properans	10.0	20.0	.	.	.	.		
Amara communis	5.0	8.7	41.3	30.1	.	.		
Bembidion tetracolum	5.0	10.0	.	.	1.1	2.2		
Harpalus rufipes	4.2	8.3	.	.	.	.		
Amara familiaris	.	.	77.5	3.5	.	.		
Carabus granulates	.	.	22.5	3.5	.	.		
Bembidion bipunctatum	.	.	.	.	4.3	7.5		
Clivina fossor	.	.	.	.	1.1	2.2		
Pterostichus diligens	.	.	.	.	75.8	6.2		
Pterostichus nigrita	.	.	.	.	5.0	4.1		
Pterostichus strenuus	.	.	.	.	12.4	6.5		
Araneae/species richness	[a] 6.3	1.7	[b] 17.0	0.0	[c] 27.5	0.6	308.6	<0.01
Erigone atra	61.3	15.9	38.6	2.9	11.3	2.8	4.8	0.08
Bathyphantes parvulus	[b] 13.4	3.4	[b] 9.7	1.0	[a] 6.8	2.8	6.5	0.04
Oedothorax fuscus	[b] 9.9	7.4	[b] 10.9	0.7	[a] 6.0	0.9	6.5	0.04
Erigone dentipalpis	7.2	6.5	2.8	0.5	0.3	0.3	-	-
Bathyphantes gracilis	[a] 3.6	2.5	[a] 4.8	2.4	[b] 7.2	2.5	7.2	0.02
Lepthoroptrum robustum	2.7	3.3	.	.	0.1	0.3	-	-
Oedothorax retusus	[a] 2.8	3.7	[a] 1.3	0.4	[b] 3.1	1.0	6.8	0.03
Diplocephalus permixtus	[a] 0.9	1.8	.	.	[b] 31.0	7.9	66.2	< 0.01
Pardosa amentata	[a] 0.9	1.7	[b] 3.5	2.0	[b] 4.6	1.7	7.3	0.02
Porrhomma pallidum	1.0	1.9	.	.	0.3	0.3		
Pachygnatha degeeri	.	.	12.6	2.8	0.4	0.5		
Araeoncus humilis	.	.	3.0	3.1	2.3	1.7		
Tiso vagans	.	.	5.9	5.4	.	.		
Erigonella hiemalis	.	.	1.2	1.7	.	.		
Pelecopsis parallela	.	.	1.6	2.2	.	.		
Gongylidiellum vivum	.	.	.	.	8.6	3.9		
Centromerita bicolor	.	.	.	.	3.2	0.6		
Walckenaeria antica	.	.	.	.	2.6	1.0		
Gongylidiellum latebricola	.	.	.	.	1.8	1.5		
Pirata piraticus	.	.	.	.	1.8	0.9		
Dicymbium nigrum	.	.	.	.	1.5	0.7		
Diplocephalus cristatus	.	.	.	.	1.2	0.5		
Pachygnatha clercki	.	.	.	.	1.1	0.9		

The situation was similar at the two grassland sites; Diptera and Lumbricidae were the groups with the highest biomass, followed by Collembola. Only in the wet grassland was the gastropod biomass higher than that of Collembola. Another important group in regard to abundance and biomass was the coleopteran family of Staphylinidae. On average, more than 100 ind./m², including larvae, were found on all three sites, with the highest values in the wet grassland. It is interesting to note that the species in the agrarian field were smallest with 0.2 mg/ind, intermediate in the dry grassland with 0.8 mg/ind and largest in the wet grassland with 1.6 mg/ind.

Table 2: Abundance (ind. m^{-2}) and biomass (mg m^{-2}) of the main animal groups in vegetation, soil surface and in the soil (upper 5 cm) of the three investigated sites.

	Soil				Floor				Vegetation			
Taxon	Abundance		Biomass (mg)		Abundance		Biomass (mg)		Abundance		Biomass (mg)	
	mean	s.d	mean	s.d	Mean	s.d	mean	s.d	mean	s.d	Mean	s.d
Argicult field												
Acari	155	48	7	3	2040	587	66	12				
Collembola	1407	138	32	8	3414	489	123	43				
Diptera	197	46	86	60	272	87	304	87				
Araneae	3	7	0.3	0.6	24	4	12	1				
Lumbicidae	23	7	327	180	1	0.3	63	87				
Carabidae	7	7	7	13	4	0.6	13.7	10				
Cantharidae	.	.	.	.	5	5	36	29				
Staphylinidae	42	32	6	4	61	10	18	2				
Pasture												
Acari	90	55	3	2	1085	107	17	0.3	.	.	.	.
Collembola	607	55	17	0.4	4837	356	111	3	.	.	.	.
Diptera	90	73	10	11	399	164	1274	669	81	14.4	36	5
Araneae	7	9	23	32	75	15	54	20	33	8.2	27	1
Diplopoda	.	.	.	.	0.2	0.3	14	20	.	.	.	.
Lumbicidae	32	27	2148	1475	4	1	343	299	.	.	.	.
Gastropoda	.	.	.	.	9	3	59	26	2	0.9	3	1
Carabidae	7	9	1	1	5	1	46	18	1	1	6	9
Cantharidae	.	.	.	.	52	0	132	62	0.3	0.5	0.1	0.1
Staphylinidae	7	9	0.2	0.3	115	6	97	17	4	0.5	11	15
wet grassland												
Acari	219	0	16.3	3	155	6.3	12	0.2	.	.	.	.
Collembola	1261	447	41.6	11	2571	231.2	162	19	.	.	.	.
Diptera	213	119	109.5	54	334	43.1	3886	138	76	3	82	22
Araneae	16	9	8.7	19	102	16.7	73	7	62	12	113	20
Chilopoda	3	9	1.6	5	0.4	0.1	7	1	.	.	.	.
Lumbicidae	155	37	5154.8	2470	7	0.9	838	292	.	.	.	.
Gastropoda	.	.	.	.	32	8.4	1067	520	72	13	1310	1433
Carabidae	3	0	11.3	0	8	1.6	62	30	.	.	.	.
Cantharidae	.	.	.	.	1	0.2	6	8	0.4	0.7	1	1
Staphylinidae	39	9	45.7	49	86	3.0	159	36	5	0.2	6.4	0.6

The decrease of biomass in the different taxa corresponds to the decrease of the mean biomass of individuals (Table 2). Most animal groups had smaller individuals in the agrarian fields than in the two grassland systems. Only weight of individual earthworms was not significantly different between the systems. Cantharidae larvae were largest in the dry grassland and smallest in the wet grassland.

Table 3: Mean fresh weight of individuals of different invertebrate groups at the three investigated sites.

Taxon	Agricultural field		Dry pasture		Wet grassland		F	Df	p
	mean	s.d	Mean	s.d	Mean	s.d			
Acari	[a]0.044	0.005	[a]0.056	0.003	[b]0.086	0.011	22.23	4.40	0.005
Collembola	[a]0.002	<0.001	[b]0.003	<0.001	[b]0.003	<0.001	15.35	4.58	0.010
Diptera	[a]0.148	0.051	[a]0.286	0.064	[b]0.779	0.282	10.01	2.86	0.051
Araneae	[a]0.442	0.010	[b]0.941	0.009	[b]0.695	0.004	63.03	2.77	0.005
Lumbicidae	36.506	29.838	48.048	17.559	30.704	1.986	0.78	2.02	0.559
Gastropoda	0.000	0.000	2.753	0.086	2.253	0.753	79.568		0.164
Carabidae	[a]1.717	1.071	[b]5.700	2.048	[b]4.039	1.176	4.85	2.52	0.136
Cantharidae	[b]16.275	6.554	[c]84.800	8.344	[a]5.775	3.084	66.2	2.33	0.009
Staphylinidae	[a]0.119	0.017	[b]0.299	0.036	[b]0.397	0.079	33.94	2.34	0.018

Yearly dynamics

The annual dynamics of biomass varied between the main soil fauna groups of the macrofauna (Fig. 1). Earthworms showed seasonal changes in the agricultural field and the dry grassland with high values during late autumn and winter. In contrast, the biomass changes in the wet grassland seem to vary between years and not between seasons. Diptera larvae, which account for the total biomass of the soil fauna to a great extent, showed nearly no variation in the agricultural field but high seasonal changes in the dry and the wet grassland. Seasonal maxima in the dry pasture and the wet grassland were found in the winter months and in late summer. In the wet grassland, seasonal changes showed higher variations than in the dry pasture; there the late summer maximum might exceed the winter maxima. Araneae go through more changes between years than between seasons in the agricultural fields and the dry pasture, but have a distinct peak in the wet grassland in summer. The biomass changes of the Cantharidae larvae exhibited seasonal maxima in the winter months in the dry pasture; however, maxima varied distinctly between the years. The biomass maxima of Carabidae differed distinctly between the three sites and between the years. In one year, clear peaks developed in spring and autumn, e.g. 1989 in the agricultural field, but were absent in the other years. In contrast to Carabidae, Staphylinidae biomass showed clear seasonal maxima in the dry pasture and the wet grassland with high values from late winter to early summer.

Discussion

The data clearly document that the species richness on grasslands are higher than on agricultural fields for nearly all of the animal groups studied. With the exception of Carabidae, species were not restricted to the agricultural field. However, many species found in the two grassland types were not found on the agricultural field. Collembolan composition differed less between the sites and had also the highest species density of all groups identified to species level. The small size of Collembola might be one reason for this result, since the number of specimens caught was distinctly higher for that group than for any other group. PONGE et al (2003) found a significant decrease of collembolan species richness and abundance from deciduous forests to cereal crops. Nevertheless, intensity of land use had no influence on the species richness. FILSER at al. (2002) also found only small changes in the composition of collembolan assemblages after the conversion from grassland to agricultural field. Correspondingly, after the conversion from agricultural field to grassland, no changes in species richness and low changes in assemblage composition were shown (CHAUVAT et al. 2007). Similarly as in the studied area, the decrease of *Lepidocyrtes cyaneus* indicated the change from grassland to crop fields. The composition of the collembolan assemblage on the agricultural field corresponded to other field assemblages in northern Germany. *Cryptopygus thermophilus* and *Isotomurus palustris* were also dominant in other investigations of agricultural fields (LÜBBEN 1991). Although the composition varies distinctly, several species seem to occur constantly on agricultural fields, e.g. *I. palustris* and *Isotoma notabilis* (HEIMANN-DETLEFSEN 1991, ALVAREZ et al. 2001, SCHRADER et al. 2006). LÜBBEN (1991) found high variations for the occurrence of *I. notabilis* and *C. thermophilus* without having any explanation for the ecological demands of these species.

Staphylinidae, Carabidae and Araneae were usually studied using pitfall traps, which reflect totally different compositions when compared to sampling methods that measure the density of species (BASEDOW et al. 1988). The adequate methods of collecting invertebrate species richness in agrarian ecosystems are still under debate, but suction traps seem to be the best for measuring density and biomass (STANDEN 2000).

Data for Staphylinidae are particularly rare. GILGENBERG (1986) studied the Staphylinidae fauna of agricultural fields. Because she worked with pitfall traps, large species, e.g. *Philonthus cognatus* and *Tachinus rufipes*, dominated the fields, whereas small species, e.g. *Amischa analis* and *Atheta fungi*, which dominated in the present investigation, were less frequent. The tremendous changes of the assemblage composition from agricultural field to wet grassland show that Staphylinidae distinctly react to the change of land-use and site parameters. Although dominant species, e.g. *Oxypoda sericea*, *Amischa analis* and *Atheta fungi*, live in a wide range of ecological conditions with small ecological preferences, the change from dry to wet grassland causes a significant change in the assemblage composition. Carabidae are much better investigated than Staphylinidae. For Schleswig-Holstein, IRMLER & GÜRLICH (2004) differentiated five assemblages on agricultural fields depending on field size and sand content, and six assemblages in grasslands depending on moisture and sand content of the soil. The investigated field belongs to the assemblage on sandy soils, with *Pterostichus melanarius* and *Harpalus rufipes* as dominant species. The wet grassland corresponded with the assemblage of wet grassland on peat soils, the dry pasture with the grassland on very sandy soils with both *Pterostichus nigrita*, *Carabus granulates* and *Poecilus versicolor*, respectively, as dominant species. However, due to the density measuring method used in the present investigation, smaller species with less running activity were dominant: *Bembidon lampros* on the field, *Amara familiaris* on the dry grassland and *Pterostichus diligens* on the wet grassland. These species were also characteristic when using pitfall traps but were found in lower numbers. The reasons for the change in carabid assemblages from field to wet grassland can be primarily referred to the change in site conditions rather than to different management practices. Changes in management practices of grassland caused only small changes in the assemblage composition of Carabidae (IRMLER et al. 1998). For spiders (Arenaea), both four and three assemblages for agricultural fields and grassland, respectively, were found in Schleswig-Holstein (REINKE & IRMLER 1994). Grassland types were separated along the moisture gradient and field types along the gradient of the sand content. However, the differentiation between field assemblages were low and farming practices such as organic and intensive farming played a secondary role. According to BLICK et al. (2000), the spider fauna on agricultural fields in Europe show a very low variation. *Erigone atra* was dominant in all agrarian ecosystems irrespective of their field or grassland use, and *Diplocephalus permixtus* was dominant in wet grassland. Thus, the spider assemblage on the described field and grasslands seem to be representative for wide parts of the European fauna for the investigated types of ecosystems.

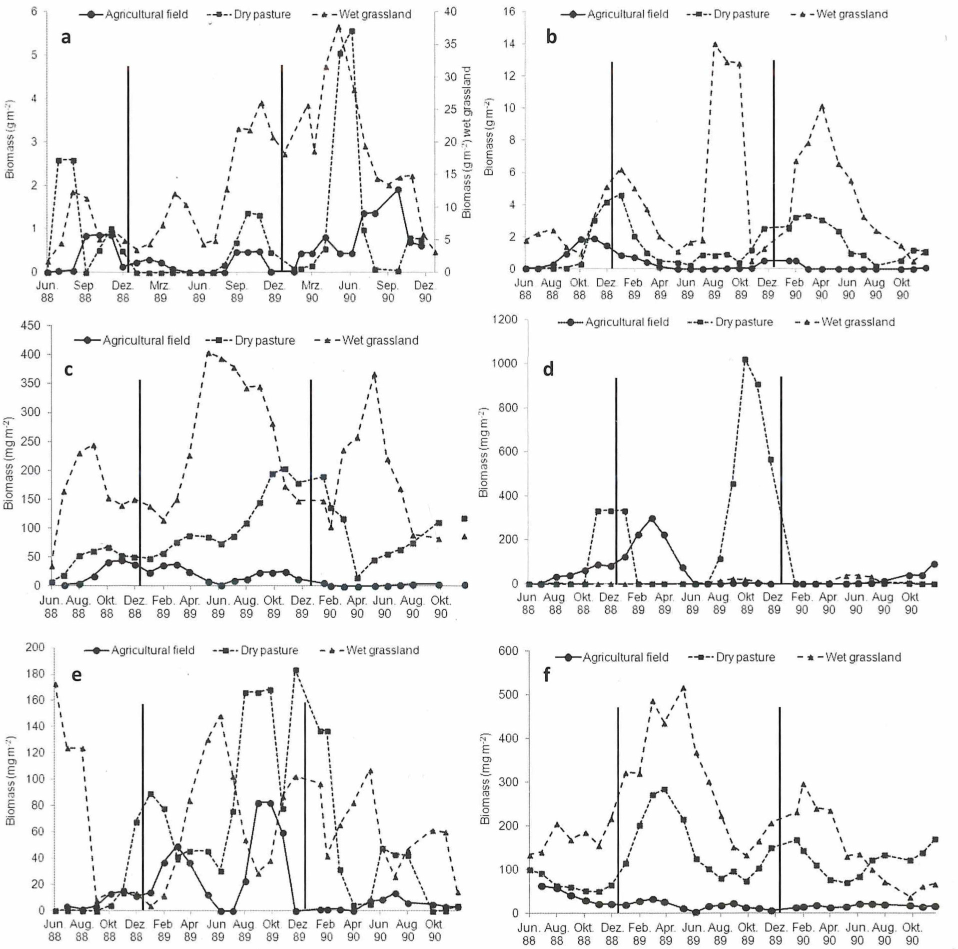

Fig. 1 Biomass dynamics of main soil fauna groups: (a) Lumbricidae, (b) Diptera larvae, (c) Araneae, (d) Cantharidae larvae, (e) Carabidae, (f) Staphylinidae

TUCKER (1992) found the highest invertebrate densities on permanent grassland which corresponded with high densities of invertebrate-feeding birds, intermediate on cereal stubble and lowest on winter cereals. In the present investigation, the soil floor provides the highest biomass compared to the mineral soil or vegetation layer. Irrespective of the soil meso-fauna, i.e. the small Acari and Collembola, only the Lumbricidae biomass was higher in the soil layer. Although the collembolan abundance was lowest in the wet grassland, the biomass was highest there. This is because there is a greater number of larger species in both grasslands in comparison to the agricultural field; this can be derived from the higher mean individual biomasses. Thus, small changes in the species composition might cause large changes for the predatory species that feed on prey of a specific size. This discrepancy between total biomass and individual biomass is still more developed in several other fauna groups, which means that larger individuals live in the grassland than in the agrarian field. Only Lumbricidae individuals showed equal mean sizes in all three ecosystems. Both total biomass and individual biomass, must be taken into consideration regarding the importance of invertebrates for larger predators such as birds. Bird species that mainly feed on soil living Lumbricidae will find similar amounts of prey at fields and at grasslands. Since hunting on fields is possibly much easier than hunting on pastures with denser soils, soil density is important for a successful hunt. However, for birds that feed on arthropods living on the soil floor or among the vegetation, the individual size of their prey might be important. Thus, birds feeding on Diptera, Coleoptera, and spiders will be more successful at grassland ecosystems because a larger individual size of prey is combined with a greater total biomass (HOLLAND et al. 2006). The importance of grassland and sward for the food supply of birds has already been proven by many investigations (ATKINSON et al. 2005, VICKERY et al. 2009).

The importance of a mosaic of different ecosystems is also stressed by the different biomass dynamics. Many invertebrate groups differ in their seasonal occurrence depending on the ecosystem type. THOMAS & JEPSON (1997) investigated the yearly dynamics of spiders in 4 cereal fields and 3 grassland sites. They found various dynamics depending on the usage of autumn insecticides or the cutting regime of grassland. On average, highest densities were reached in June and July. However, autumn cultivation, such as for winter-wheat or corn, resulted in a reduction of spider densities by 89 % and in a second smaller spider maximum in late autumn. Thus, the present change in agriculture to cultivate winter crops is one reason for the decrease in invertebrate density and loss of seasonality. Many invertebrates benefit from contiguous ecosystems types. Lumbricidae, for example, had higher biomasses in the wet grassland at periods in which their biomass decreased in the higher elevated ecosystems because of low moisture levels. Cantharid larvae had high biomasses in the pasture at periods in which low biomasses were found in the field or the wet grassland. The importance of contiguous winter-moist and summer-moist areas was also stressed by IRMLER et al. (2008) who studied the population of the Diptera species *Dilophus febrilis*. This species has its larval development in a range of 13-50% soil moisture, which is only attained in contiguous habitats when moisture seasonally changes for the summer generation and the winter generation. According to KLEIJN et al. (2006) the biodiversity benefits from agri-environmental schemes. The species richness for the total landscape was most strongly affected by the number of adjacent semi-natural habitat patches (HENDRICKX et al. 2007). Thus, bird diversity will profit from a mosaic of agrarian fields and grassland because the food supply by invertebrates offers more diverse prey in regard to biomass, individual size of prey and seasonality.

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