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Diversity and abundance of the coleopteran fauna from organic and conventional management systems in southern England

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Abstract

1 Studies of the epigeal coleopteran fauna on five pairs of organic and conventional farms were carried out between May and July 1994 in southern England using pitfall trapping. A total of 27 749 individuals and 140 species were identified. Overall, abundance of Coleoptera was greatest on organically managed farms.

2 Ground beetles (Coleoptera: Carabidae) and staphylinid beetles (Col. Staphylinidae) formed 79.7% and 16.7%, respectively, of the total catch. *Pterostichus melanarius* was the dominant carabid among the 45 species captured and significantly higher numbers were found in organic farms. *Tachinus signatus* was the most common of 44 staphylinid species, and was significantly more abundant on conventional farms.

3 For carabids, the log-series α diversity index was higher on conventional farms but was not statistically different from that calculated for organic farms. The α index was identical for staphylinid species from organic and conventional farms. Diversity was significantly higher from conventional farms when data were combined for all of the recorded coleopteran species.

4 From this study, it appears that the main effect of farming practice is to influence the overall abundance and dominance of particular species, and the lower diversity of organic farms is a consequence of the large increase in dominance of a single species, namely *P. melanarius*.

Keywords α Diversity index, carabids, Coleoptera, farming systems, staphylinids.

Introduction

The diversity of species and numbers of individuals in arthropod communities recorded from agricultural systems vary according to the arthropod group, cropping system, plant density, pesticide use and management philosophy as well as many other biotic and abiotic factors (Förster, 1991; Kremen *et al*., 1993). Carabid and staphylinid beetles are two of the most common taxa of above-ground, or epigeal, polyphagous predators in agroecosystems. Quantification of predation by carabids has been improved with the use of monoclonal antibodies, and recent studies have revealed the importance of earthworms and slugs as prey sources (Symondson & Liddell, 1993; Symondson *et al*., 2000; Harwood *et al*., 2001). Both carabids and staphylinids have been used as bioindicators of environmental changes in natural and modified ecosystems because of their relative ease of capture by pitfall trapping, responsiveness to environmental conditions, mobility and widespread distributions (Thiele, 1977; Dritschilo & Wanner, 1980; Good & Giller, 1991; Kennedy, 1992; Luff *et al*., 1992). However, there is less information concerning the effects of farming systems on carabid and staphylinid fauna in England compared with mainland Europe. Previous reports in England have concentrated on arthropods other than carabids and staphylinids inhabiting cereal crop canopies (Moreby *et al*., 1994).

The current study was performed to determine whether there were any differences in numbers and species of Coleoptera, especially carabids and staphylinids, between fields that had been farmed with the use of inorganic fertilisers and chemical pesticides (conventional system), and fields that were managed without the use of any synthetic chemicals (organic system). These fields had been approved for the cultivation of organic crops by the UK Soil Association and had not received chemical inputs for a minimum of 5 years before sampling for Coleoptera. The original

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objective of the study was to determine potential arthropod food sources for farmland birds, which has been reported elsewhere (Brooks *et al*., 1995; Chamberlain *et al*., 1999). In this work, we consider some aspects of coleopteran diversity and abundance in more detail.

Materials and methods

Farms and sampling procedures

Studies were performed between May and July 1994 at five paired sites in the southern and eastern Midlands of England, in the counties of Lincolnshire, Oxfordshire, Suffolk and Wiltshire. Each site consisted of one organic and one conventional farm, which had been selected for proximity. Two fields were sampled from each farm at each site. All of the fields chosen contained winter cereals except one field in an organic farm containing spring oats. Organic farms grew crops without the use of inorganic fertilisers or pesticides, and organic fields were 4–8 ha in size. Conventional fields were 4–14 ha in size and had been treated with inorganic fertiliser as well as with several insecticide applications (mostly organophosphate aphicides) during the study period.

Within each field, five pitfall traps were placed in a transect from a field margin towards the field centre at 20-m intervals. Each trap consisted of an outer plastic cylinder (102 mm length, 65 mm internal diameter) sunk into the soil, which contained a white plastic cup (77×60 mm) with approximately 60–80 mL of a 1 : 1 mixture of ethylene glycol and tap water as a preservative solution. Traps were protected from rainfall by inverted plastic dishes (132 mm diameter) suspended 50–80 mm above the traps with wire loops. Collections of insects were made for 10–14 days, after which the traps were replaced. Coleoptera from pitfall trap catches were sorted, identified and counted to species level under $\times 20$ magnification with a stereo microscope, except in rare cases where intractable taxonomic features prevented this. Coleopteran nomenclature and taxonomy was based on Kloet & Hincks (1977).

Data analysis

Nested analyses of variance (ANOVA) were performed using Genstat 5 (Payne *et al*. 1995) to determine whether there were any differences in abundance between management systems for selected coleopteran groups or species. Insect catches were used from all five pitfall traps placed in a field, and each field within a farm was considered as a replicate. Data were transformed using $\log_{10}(x+1)$, where x = number of individuals per trap per sample period, to stabilize variances (Sokal & Rohlf, 1995). Back-transformed means and 95% confidence limits are presented in text and figures.

Species lists, abundances and numbers of species (species richness) were compiled based on catches from the organic and conventional farms. The log-series α diversity index was used as a measure of biodiversity. This diversity index is considered to be superior to commonly used indices such as the Shannon–Weiner information statistic or Simpson's Index (Taylor *et al*., 1976; Magurran, 1988). The maximum likelihood estimate, $\acute{\alpha}$, of α can be derived from

$$S = \acute{\alpha} \log (1 + N/\acute{\alpha})$$

where S = number of species in the sample, and N = number of individuals in the sample.

Values of $\acute{\alpha}$ were computed using the Maximum Likelihood Program (Ross, 1987) and tested using two-way parametric ANOVA to compare between farm pairs and management systems for the major families of Coleoptera recorded.

Results

Total species and numbers of Coleoptera

In total, 27 749 individuals from 140 coleopteran species were identified and recorded during the 8-week study period. Carabid beetles formed the dominant group of epigeal Coleoptera in pitfall trap catches, comprising 79.7% of all individuals, whereas staphylinids and other Coleoptera

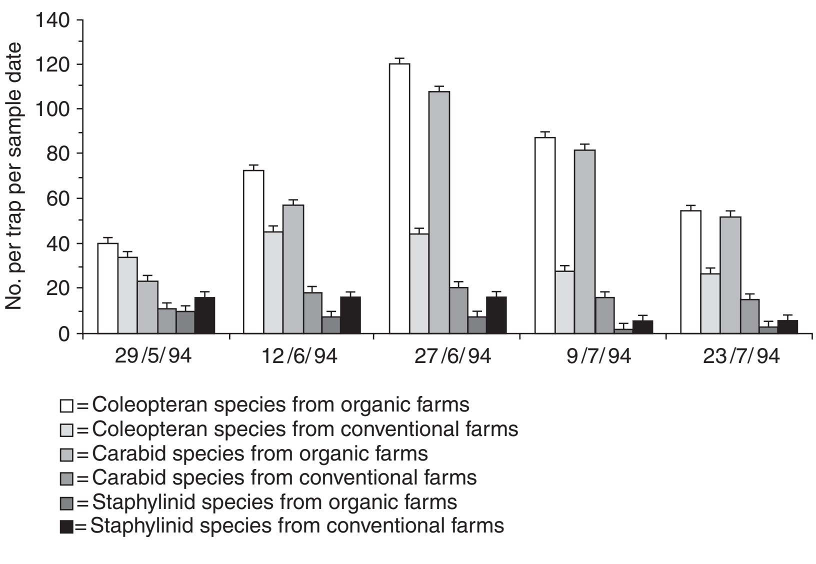

Figure 1 Detransformed mean abundances for all coleopteran, carabid and staphylinid species from organic and conventional farms.

formed 16.7% and 3.7% of all individuals, respectively. A common ά of 16.5 ± 1.2 was obtained by combining data between all sites and the two management systems. However, ά was greater for conventionally managed farms (ά = 10.2 ± 0.7) than for organic farms (ά = 8.2 ± 0.5; $F_{1,8} = 7.6$, $P < 0.05$).

Coleopteran abundance was larger overall on organic farms ($F_{1,10} = 17.8$, $P < 0.05$) and differed between sample dates ($F_{4,32} = 6.7$, $P < 0.001$). For abundance, there was also a significant interaction between management system and sample date ($F_{4,32} = 3.2$, $P < 0.05$), with abundance greatest in mid-June on organic farms (Fig. 1).

Carabid beetles

A total of 22 112 carabid beetles from 45 species were recorded (Table 1). The five most commonly trapped carabids were *Pterostichus melanarius* (Illiger), *Agonum dorsale*

Table 1 Overall abundances of carabid species recorded from pitfall traps

	Management system		
Carabid species	Organic	Conventional	Total
Pterostichus melanarius (Illiger)	9386	3403	12789
Agonum dorsale (Pontoppidan)	979	1573	2552
Pterostichus madidus (Fabricius)	2020	157	2177
Pterostichus cupreus (Linnaeus)	963	162	1125
Nebria brevicollis (Fabricius)	718	141	859
Trechus quadristriatus (Schrank)	652	318	970
Harpalus rufipes (Degeer)	345	71	416
Pterostichus niger (Schaller)	202	4	206
Bembidion lampros (Herbst)	93	94	187
Loricera pilicornis (Fabricius)	74	109	183
Calathus fuscipes (Goeze)	83	69	152
Harpalus affinis (Schrank)	93	11	104
Pterostichus strenuus (Panzer)	13	65	78
Notiophilus bigattatus (Fabricius)	47	20	67
Bembidion obtusum Serville	22	14	36
Bembidion lunulatum (Fourcroy)	20	8	28
Bembidion guttula (Fabricius)	11	16	27
Amara similata (Gyllenhall)	13	10	23
Agonum muelleri (Herbst)	15	5	20
Bembidion tetracolum Say	10	5	15
Calathus piceus (Marsham)	0	14	14
Demetrias atricapillus (Linnaeus)	7	10	17
Abax parallelepipedus (Piller & Mitterpacher)	1	5	6
Amara plebeja (Gyllenhall)	3	3	6
Carabus violaceous Linnaeus	1	5	6
Synuchus nivalis (Illiger)	0	6	6
Amara aenea (Degeer)	2	2	4
Bembidion quadrimaculatum (Linnaeus)	2	3	5
Amara familiaris (Duftschmid)	2	2	4
Pterostichus nigrita (Paykull)	1	3	4
Amara lunicollis Schiödte	1	2	3
Clivina fossor (Linnaeus)	2	1	3
Harpalus rufibarbis (Fabricius)	0	3	3
Pterostichus macer (Marsham)	3	0	3
Calathus cinctus Motschulsky	0	2	2
Stomis pumicatus (Panzer)	1	2	3
Agonum obscurum (Herbst)	0	1	1
Amara aulica (Panzer)	0	1	1
Amara bifrons (Gyllenhall)	1	0	1
Amara eurynota (Panzer)	1	0	1
Amara ovata (Fabricius)	0	1	1
Asaphidion flavipes (Linnaeus)	0	1	1
Laemostenus terricola (Herbst)	1	0	1
Pterostichus longicollis (Duftschmid)	1	0	1
Pterostichus vernalis (Panzer)	1	0	1
Total individuals	15790	6322	22112
Total species	37	39	45
ά	2.9 ± 0.3	3.8 ± 0.4	5.4 ± 0.9

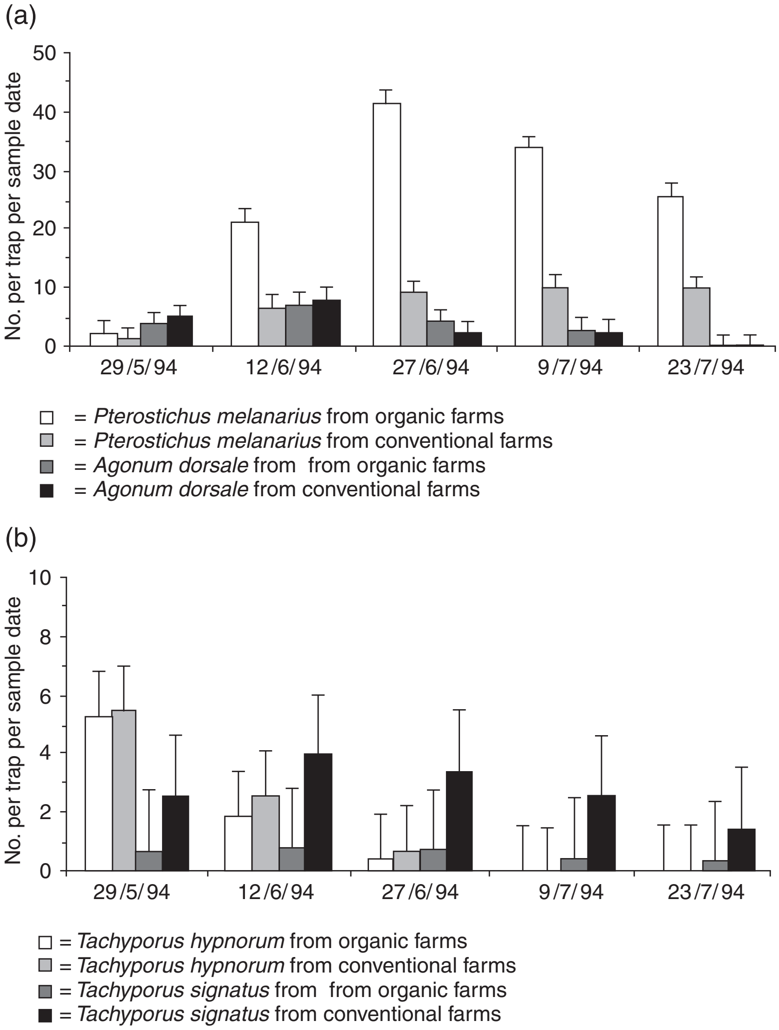

Figure 2 (a) Detransformed mean abundances (± 95% CL) for *Pterostichus melanarius* and *Agonum dorsale* from organic and conventional farms. (b) Detransformed mean abundances (± 95% CL) for *Tachyporus signatus* and *Tachyporus hypnorum* from organic and conventional farms.

(Pontoppidan), *P. madidus* (Fabricius), *P. cupreus* (Linnaeus) and *Trechus quadristriatus* (Schrank), and these comprised 88.7% of all carabid species. Although diversity was lower from organic farms ($\acute{\alpha} = 2.9 \pm 0.3$) compared with conventional farms ($\acute{\alpha} = 3.8 \pm 0.4$), this was not statistically significant ($F_{1,8} = 2.31$, $P > 0.05$), and a common value of 5.4 ± 0.9 was computed for $\acute{\alpha}$ by combining results from the two management systems. The largest diversity was from a conventional farm ($\acute{\alpha} = 7.3 \pm 2.1$) where the lowest numbers of *P. melanarius* were collected, and the lowest value was from an organic farm ($\acute{\alpha} = 2.4 \pm 0.6$). These two farms were from the site where only three pitfall trap collections were possible. *Pterostichus melanarius* accounted for 8.7% ($n = 92$) and 73.2% ($n = 2342$) of carabid individuals from the conventional and organic farm, respectively.

Carabid abundance was 3.7-fold greater on organic than conventional farms ($F_{1,10} = 40.2$, $P < 0.001$). Carabid abundance differed between sample dates ($F_{4,32} = 11.6$, $P < 0.01$) and closely followed the trend for all Coleoptera (Fig. 1). Two carabid species were significantly more abundant on organic farms: *P. melanarius* ($F_{1,10} = 18.9$, $P < 0.001$) and *P. madidus* ($F_{1,10} = 5.4$, $P < 0.05$), but there were no significant differences between management systems for *A. dorsale* ($F_{1,10} = 0.1$, $P > 0.05$), *P. cupreus* ($F_{1,10} = 3.5$, $P > 0.05$) or *T. quadristriatus* ($F_{1,10} = 0.4$, $P > 0.05$). Numbers of *P. melanarius* differed between sample dates ($F_{4,32} = 39.2$, $P < 0.001$), with a peak in mid-June from organic farms (Fig. 2). This was largely responsible for the similar trend noted for abundance of all Coleoptera (Fig. 1).

Staphylinid beetles

Among 4623 individuals and 44 species of staphylinid beetles, the five most common were *Tachinus signatus* Gravenhorst, Aleocharinae spp., *Tachyporus hypnorum* (Fabricius), *Philonthus cognatus* Stephens and *Anotylus inustus* (Gravenhorst) (Table 2). These five species accounted for 94.3% of all staphylinids recorded. Pooled values for $\acute{\alpha}$ from organic and conventional farms were identical (3.6 ± 0.4), and not statistically different ($F_{1,8} = 0.01$, $P > 0.05$), and an $\acute{\alpha}$ of 5.8 ± 0.8 was obtained by combining data from the two management systems. The lowest and highest diversities were from organic farms ($\acute{\alpha} = 2.6 \pm 0.9$ and 4.7 ± 1.2).

Table 2 Overall abundances of staphylinid species recorded from pitfall traps

Species	Management system		
	Organic	Conventional	Total
Tachinus signatus Gravenhorst	631	967	1598
Aleocharinae spp.	409	856	1265
Tachyporus hypnorum (Fabricius)	380	482	862
Philonthus cognatus Stephens	212	205	417
Anotylus inustus (Gravenhorst)	66	152	218
Philonthus laminatus (Creutzer)	14	29	43
Anotylus sculpturatus (Gravenhorst)	6	19	25
Tachyporus obtusus (Linnaeus)	25	8	33
Anotylus rugosus (Fabricius)	11	12	23
Xantholinus glabratus (Gravenhorst)	14	4	18
Tachyporus solutus Erichson	7	6	13
Philonthus varians (Paykull)	3	8	11
Omalium caesum Gravenhorst	1	7	8
Lathrobium fulvipenne (Gravenhorst)	4	5	9
Xantholinus linearis (Olivier)	3	5	8
Philonthus decorus (Gravenhorst)	2	6	8
Lathrobium geminum Kraatz	5	0	5
Stenus clavicornis (Scopoli)	3	3	6
Xantholinus longiventris Heer	1	1	2
Tachyporus nitidulus (Fabricius)	2	3	5
Rugilus orbiculatus (Paykull)	1	3	4
Ocypus (= *Staphylinus*) *olens* (Müller)	3	0	3
Gyrohypnus punctulatus (Paykull)	1	2	3
Tachyporus chrysomelinus (Linnaeus)	1	5	6
Quedius cinctus (Paykull)	2	0	2
Cypha longicornis (Paykull)	2	0	2
Othius laeviusculus Stephens	1	0	1
Stenus subaeneus Erichson	1	3	4
Philonthus marginatus (Ström)	1	1	2
Anotylus tetracarinatus (Block)	0	2	2
Lesteva longoelytrata (Goeze)	0	2	2
Stenus bimaculatus Gyllenhal	1	0	1
Quedius tristis (Gravenhorst)	1	0	1
Quedius longicornis Kraatz	1	0	1
Quedius semiaeneus (Stephens)	0	1	1
Quedius fuliginosus (Gravenhorst)	0	1	1
Staphylinus globulifer Fourcroy	1	0	1
Mycetoporus splendidus (Gravenhorst)	1	0	1
Mycetoporus longulus Mannerheim	0	1	1
Bolitobius analis (Fabricius)	0	1	1
Coprophilus striatulus (Fabricius)	0	1	1
Omalium italicum Bernhauer	0	1	1
Philonthus intermedius (Boisduval & Lacordaire)	0	1	1
Philonthus ebeninus (Gravenhorst)	1	0	1
Total individuals	1818	2805	4623
Total species	35	34	44
ά	3.5 ± 0.5	3.6 ± 0.4	7.0 ± 1.1

Staphylinid abundance was 2.3-fold greater on conventional than organic farms ($F_{1,10} = 7.5$, $P < 0.05$) and declined on both types of farms during the study period ($F_{4,32} = 20.4$, $P < 0.001$) (Fig. 1). Of the dominant staphylinid species, *T. signatus* was more numerous on conventional farms ($F_{1,10} = 6.7$, $P < 0.05$) and Aleocharinae spp. were found in greater numbers on organic farms ($F_{1,10} = 11.7$, $P > 0.01$). There were no significant differences between management systems for *A. inustus* ($F_{1,10} = 1.8$, $P > 0.05$), *P. cognatus* ($F_{1,10} = 1.0$, $P > 0.05$) or *T. hypnorum* ($F_{1,10} = 1.4$, $P > 0.05$). Numbers declined over the study period for *T. hypnorum* ($F_{4,32} = 45.8$, $P < 0.001$) and *T. signatus* ($F_{4,32} = 3.6$, $P < 0.05$) (Fig. 3).

Other Coleoptera

Coleoptera other than Carabidae or Staphylinidae comprised 1014 individuals from 51 species and 21 families (Table 3). The most numerous species was *Choleva angustata* (Fabricius) from the Family Leiodidae. Diversity

Table 3 Overall abundances of coleopteran species excluding Carabidae and Staphylinidae

	Management system		
Family: species	Organic	Conventional	Total
HYDROPHILIDAE:			
Helophorus rufipes (Bosc d'Antic)	37	28	65
Megasternum obscurum (Marsham)	8	0	8
Helophorus brevipalpis Bedel	1	1	2
Subtotal	46	29	75
HISTERIDAE:			
Paralister carbonarius (Hoffmann)	0	1	1
LEIODIDAE:			
Ptomaphagus subvillosus (Goeze)	73	131	204
Choleva angustata (Fabricius)	49	193	242
Choleva agilis (Illiger)	0	3	3
Subtotal	122	327	449
SILPHIDAE:			
Nicrophorus vespillo (Linnaeus)	1	5	6
SCARABAEIDAE:			
Aphodius granarius (Linnaeus)	2	1	3
SCIRTIDAE:			
Microcara testacea (Linnaeus)	1	0	1
ELATERIDAE:			
Agriotes obscurus (Linnaeus)	21	3	24
Fleutiauxellus quadripustulatus (Fabricius)	11	1	12
Agriotes sputator (Linnaeus)	2	1	3
Athous bicolor (Goeze)	4	1	5
Athous hirtus (Herbst)	1	0	1
Athous haemorrhoidalis (Fabricius)	1	0	1
Agriotes pallidulus (Illiger)	0	1	1
Subtotal	40	7	47
CANTHARIDAE:			
Cantharis rustica Fallén	27	0	27
Cantharis rufa Linnaeus	6	2	8
Cantharis lateralis Linnaeus	3	0	3
Cantharis livida Linnaeus	1	2	3
Malthodes minimus (Linnaeus)	10	9	19
Cantharis pallida Goeze	1	0	1
Subtotal	48	13	61
NITIDULIDAE:			
Glischrochilus hortensis (Fourcroy)	7	114	121
Meligethes spp.	5	0	5
Meligethes aeneus (Fabricius)	0	1	1
Subtotal	12	115	127
RHIZOPHAGIDAE:			
Monotoma bicolor Villa	0	3	3
CRYPTOPHAGIDAE:			
Atomaria spp.	10	27	37
PHALACRIDAE:			
Stilbus testaceus (Panzer)	1	4	5
Olibrus aeneus (Fabricius)	1	0	1
Subtotal	2	4	6
COCCINELLIDAE:			
Rhizobius litura (Fabricius)	12	1	13
LATHRIDIIDAE:			
Enicmus histrio Joy & Tomlin	11	10	21
Cortinicara gibbosa (Herbst)	6	2	8
Stephostethus lardarius (Degeer)	0	3	3
Aridius bifasciatus (Reitter)	0	2	2
Subtotal	17	17	34
SALPINGIDAE:			
Rhinosimus planirostris (Fabricius)	1	1	2

SCRAPTIIDAE:			
Anaspis frontalis (Linnaeus)	0	1	1
CERAMBYCIDAE:			
Clytus arietis (Linnaeus)	31	0	31
CHRYSOMELIDAE:			
Aphthona euphorbiae (Schrank)	4	7	11
Longitarsus spp.	0	2	2
Phyllotreta nemorum (Linnaeus)	5	0	5
Chaetocnema concinna (Marsham)	2	0	2
Chaetocnema hortensis (Fourcroy)	1	0	1
Oulema melanopa species complex	1	0	1
Subtotal	13	9	22
APIONIDAE:			
Apion dichroum Bedel	2	2	4
CURCULIONIDAE:			
Sitona lineatus (Linnaeus)	5	3	8
Barypeithes pellucidus (Boheman)	0	4	4
Phyllobius pyri (Linnaeus)	1	0	1
Amalus scortillum (Herbst)	1	0	1
Euophryum confine (Broun)	0	3	3
Subtotal	7	10	17
SCOLYTIDAE:			
Leperisinus varius (Fabricius)	3	8	11
Total individuals	363	651	1014
Total species	40	36	51
$\acute{\alpha}$	6.3 ± 0.9	5.0 ± 0.7	11.3 ± 1.8

did not differ significantly between organic ($\acute{\alpha} = 6.3 \pm 0.9$) or conventional farms ($\acute{\alpha} = 5.0 \pm 0.7$; $F_{1,8} = 1.2$, $P > 0.05$) and the common value calculated for $\acute{\alpha}$ was 9.6 ± 1.3. Abundances were too small for ANOVA to be performed on any coleopteran species in this group.

Discussion

The rate of capture in pifall traps is influenced by both the abundance and activity of individuals of a particular species. The relative importance of either one of these factors varies with changes in environmental conditions, but high levels of association have been demonstrated between activity and abundance (Baars, 1979; Lindroth, 1985), and pitfall trapping is considered a useful method to study community assemblages of epigeal arthropods (Luff & Eyre, 1988). As an alternative technique, Moreby *et al.* (1994) collected invertebrates from cereal field margins with a Dietrick vacuum sampler (D-vac) but only obtained four species of carabids and staphylinids.

Parametric two-way ANOVA was used to compare $\acute{\alpha}$ between management systems but similar results were produced when comparisons were made using Freidman's test, a non-parametric ANOVA, or weighted multiple regression, and results from these further examinations are not presented.

A significantly higher diversity, as expressed by $\acute{\alpha}$, was obtained from conventional farms when data was combined using information on all coleopteran species. However, this may be a statistical artefact caused by higher numbers of the dominant carabid *P. melanarius* in organic farms. In the Netherlands, Booij (1994) attributed a lower diversity of carabids in organically grown crops due to the dominance of *P. melanarius*. Several studies in Europe and North America showed that organic management systems increased carabid abundance and species richness but not diversity (see Kromp, 1999). Such apparently contradictory conclusions may arise if diversity is measured primarily by species richness, which is not independent of sample size (abundance). Gotelli & Colwell (2001) have recently discussed several methods to overcome some of the problems in quantifying species richness, but there are no studies to date which demonstrate that species richness measures (e.g. rarefraction techniques) are better discriminants than indices based on the underlying species frequency distributions (Kempton & Taylor, 1979).

Two diversity measures commonly used in studies of community assemblages are the Shannon–Weiner index (H′) and Simpson's index (D), which are theoretically independent of sample size. However, interpretation of both these indices should be treated with caution because they are relatively insensitive for environmental impact analyses compared with α, being particularly badly affected by small sample bias, species dominance and presence of rare species (Taylor *et al.*, 1976; Dritschilo & Erwin, 1982; Ludwig & Reynolds, 1988; Tonhasca, 1993). Both the Shannon–Weiner index and Simpson's index are only asymptotically independent of sample size. The two indices are also particularly sensitive to changes in the abundance of the dominant species in a sample, whereas the α index places an emphasis on species occurring in the middle part of the species frequency distribution. This results in α being less influenced by one or two very abundant species or by rare, vagrant, species (Taylor, 1978; Kempton, 1979). In theory, α relies on species abundances conforming to a log-series frequency distribution. However, in practice α is robust with respect to fit of the log-series model.

Simpsons' Index (D) and the Shannon–Weiner Index (H′) were computed from data in the present study in order to facilitate direct comparisons with other studies that have not used the α index (Table 4). We found H′ was generally less than 2.0, whereas Lubke (1991) reported that H′ from conventional winter wheat fields varied between 2.2 and 2.4, and Kromp & Steinberger (1992) obtained a value of 4.1 from organic wheat in Austria. In the USA, H′ varied between 1.3 and 2.3 from organic maize fields and 1.3–1.7 from conventional fields (Dritschilo & Wanner, 1980). However, as discussed, any assessments from the above comparisons have to be treated with caution because of the poor practical performance of the two indices, especially H′ which is widely used in biodiversity studies, despite its well-known shortcomings.

Of the 45 carabid species identified from organic and conventional farms, 34 species (76%) were considered to be eurytopic, without any preference for a particular habitat (den Boer, 1977). Thiele (1977) listed eight carabid species which were characteristically associated with European agricultural habitats, and *P. melanarius* was considered to be the most frequently encountered species. Carabid communities from arable fields may represent an early successional stage, reflecting the regular changes and disruptions which occur in agroecosystems, irrespective of management philosophy (Tonhasca, 1993; Ellsbury *et al.*, 1998). However, several studies have shown that carabid communities can be affected by land management. For example, some rare carabid species were only found where there was intensive cultivation of arable fields (Schnitter, 1994), and a number of carabid species usually only associated with dry grasslands were found in organic wheat fields (Kromp, 1989). Greater numbers of carabid species were recorded from un-cropped areas and conservation headlands within arable fields (Müller, 1991; Raskin *et al.*, 1992).

Carabids from our study were more numerous on organic farms compared with conventional farms, which is in agreement with previous work. Hokkanen & Holopainen (1986) found that *P. melanarius* was eight-fold more numerous in German organic fields, and Dritschilo & Wanner (1980) estimated carabid numbers were 0.2 to seven-fold greater on organic compared to conventional arable fields. Contributory factors for the higher abundances of carabids in organic systems may be the absence of direct and indirect effects from pesticide use, such as greater weed cover. There may also be greater food resources from weed seeds and prey availability from invertebrates associated with organic manures (Purvis & Curry, 1984; Hokkanen & Holopainen, 1986; Basedow, 1994). *Pterostichus melanarius* is considered to be a hygrophilic species, and is generally more abundant where plant cover provides damp, shady conditions (Thiele, 1977; Armstrong & McKinlay, 1997). Additionally, the distribution and abundance of carabids in different habitat patches of a restored meadow in Ohio, USA, were thought to be a reflection of preferences by carabid species to the thermal environment (Crist & Ahern, 1999).

There appear to be no previous studies reporting diversity indices of non-carabid beetle species from agroecosystems. For staphylinids, this may be because of the difficulty in identifying individual species (Eyre, 1998). In Ireland, Good & Giller (1991) recorded up to 15 common staphylinid species in cereals and grassland from pitfall trapping and D-vac sampling. In the present study, the dominant staphylinid species, *T. signatus*, was more abundant in conventionally managed systems, in contrast to *P. melanarius*. Possible

Table 4 Means of ά, Shannon–Weiner (H′) and Simpson's (D) diversity indices from organic and conventional farms

	Diversity index	Organic farms		Conventional farms		ANOVA[1,2]	
		Mean	Min, Max	Mean	Min, Max	System, $F_{1,9}$	Farm pair, $F_{4,9}$
Carabidae	ά	2.9	2.4, 4.0	4.2	2.8, 7.3	2.1	0.8
	H′	1.1	0.8, 1.3	1.6	1.2, 2.5	2.1	1.0
	D	0.5	0.5, 0.7	0.4	0.1, 0.5	2.1	0.9
Staphylinidae	ά	3.6	2.6, 4.7	3.6	2.8, 4.4	0.01	5.2
	H′	1.6	1.3, 2.0	1.5	0.9, 1.8	0.5	0.7
	D	0.3	0.2, 0.4	0.3	0.2, 0.6	0.2	1.3
Other Coleoptera	ά	8.2	4.8, 18.7	5.2	4.1, 7.5	1.2	1.0
	H′	2.2	1.9, 2.5	1.7	1.4, 1.9	8.1*	0.2
	D	0.2	0.1, 0.23	0.3	0.2, 0.4	9.9*	0.5
All Coleoptera	ά	8.2	6.8, 9.5	10.1	9.1, 11.1	49.8**	12.0*
	H′	1.6	1.3, 1.8	2.1	1.6, 2.4	9.8*	1.2
	D	0.4	0.3, 0.6	0.2	0.2, 0.4	9.7*	1.0
Carabidae and Staphylinidae	ά	5.4	4.0, 6.6	7.0	6.4, 7.6	3.4	1.0
	H′	1.4	1.2, 1.7	1.9	1.5, 2.2	1.8	1.1
	D	0.5	0.3, 0.6	0.3	0.2, 0.4	2.7	1.1

[1]Two-way ANOVA with farming system and farm pair as main factors; $*P < 0.05$; $**P < 0.01$.
[2]Shannon–Weiner Index transformed using $0.561(e^{H'})$-0.5, Simpson's Index transformed by (1/D)-3 (Taylor *et al.*, 1976) prior to performing ANOVAS

reasons for this may be higher crop densities in conventional fields providing a more humid microclimate (Basedow, 1994), the absence of *P. melanarius* leaving a niche for another predator, or the presence of more suitable food sources in conventionally managed fields. The greater mobility of staphylinids, which fly more readily than most carabids, may allow them to avoid pesticide applications on individual fields. Such an ability has been observed with *T. quadristriatus*, a carabid with high dispersal power (Croy, 1987). Generalist predators can cause interference by intraguild predation, cannibalism, predator–predator competition and avoidance behaviour. Snyder & Wise (1999) found the co-occurrence of both carabids and lycosid spiders in an area decreased immigration and prey consumption by both predators.

Our findings are consistent with other studies, which have shown higher abundances with organic systems but no differences between organic and conventional annual farming systems using the Shannon–Weiner Index (e.g. Hokkanen & Holopainen, 1986; Clark, 1999), although we have used the log-series α as a more powerful diversity index. In conclusion, higher numbers of carabids but lower numbers of staphylinids were recorded from organic compared with conventional farms during the single season in which our study was conducted. Diversity was only different between farming systems when data for all species were combined for all families of Coloeptera. Rather surprisingly, this indicated that conventional farms had higher diversity, as measured by log-series α. However, this is probably because *P. melanarius* was so abundant and dominant in organic fields that even a robust index, such as log-series α, was affected. Examination of the rest of the species frequency distribution indicated very little difference in diversity between the organic and conventional farming systems.

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