Ground Beetle (Coleoptera: Carabidae) Assemblages in Organic, No-Till, and Chisel-Till Cropping Systems in Maryland

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ABSTRACT Ground beetle assemblages were compared in organic, no-till, and chisel-till cropping systems of the USDA Farming Systems Project in Maryland. The cropping systems consisted of 3-yr rotations of corn (*Zea mays* L.), soybean (*Glycine max* L. Merr.), and wheat (*Triticum aestivum* L.) that were planted to corn and soybean during the 2 yr of field sampling (2001–2002). Each year, ground beetles were sampled using pitfall traps during three 9- to 14-d periods corresponding to spring, summer, and fall. A total of 2,313 specimens, representing 31 species, were collected over the 2 yr of sampling. The eight most common species represented 87% of the total specimens collected and included *Scarites quadriceps* Chaudoir, *Elaphropus anceps* (LeConte), *Bembidion rapidum* (LeConte), *Harpalus pensylvanicus* (DeGeer), *Poecilus chalcites* (Say), *Clivina impressefrons* LeConte, *Agonum punctiforme* (Say), and *Amara aenea* (DeGeer). Canonical variates analysis based on the 10 most abundant species showed that the carabid assemblages in the three cropping systems were distinguishable from each other. The organic system was found to be more different from the no-till and chisel-till systems than these two systems were from each other. In 2002, ground beetle relative abundance, measured species richness, and species diversity were greater in the organic than in the chisel-till system. Similar trends were found in 2001, but no significant differences were found in these measurements. Relatively few differences were found between the no-till and chisel-till systems. The estimated species richness of ground beetles based on several common estimators did not show differences among the three cropping systems. The potential use of ground beetles as ecological indicators is discussed.

KEY WORDS Carabidae, organic, no-till, chisel-till, cropping systems

Ground beetles are among the most common epigeic arthropods found in temperate ecosystems, including annual cropping systems (Thiele 1977, Lövei and Sunderland 1996). Their ecological role, as part of a complex of generalist predators of crop pests, has been shown by numerous studies in North America and Europe (Brust et al. 1986, Hance 1987, Clark et al. 1994, Menalled et al. 1999, Symondson et al. 2002). Other research has shown that some ground beetle species may be important in influencing weed abundance and species composition through predation on seeds (Brust and House 1988, Zhang et al. 1997, Menalled et al. 2001). Consequently, there is interest in the ability to predict the effects of management practices on ground beetle abundance and diversity in agroecosystems. Such information has potential use in guiding research on the development of more environmentally sustainable farming practices where ecological understanding and management can substitute for pesticide inputs.

Another common interest in ground beetles stems from a desire to use them as ecological indicators (Rainio and Niemela 2003). Because of their ubiquity, the relative ease in sampling them with pitfall traps, and the availability of good taxonomic keys, ground beetles have been studied as potential indicators of the effects of a wide variety of management practices, including general land use (Larsen et al. 2003), prescribed fire (Niwa and Peck 2002), managed flooding (Cartron et al. 2003), introduction of invasive plants (Dávalos and Blossey 2004), introduction of transgenic crops (French et al. 2004, Lopez et al. 2005), pesticide use (Ellsbury et al. 1998), and soil tillage (Belaoussoff et al. 2003). An implicit, although reasonable, assumption common in this area of research is that ground beetle abundance, species richness, and/or species diversity would decline with increasing magnitude or severity of human disturbance. However, studies have shown that the response of ground beetles to management disturbance is often more complicated than this.

Some studies of ground beetles in annual cropping systems indicate that there is greater ground beetle

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Table 1. Summary of management practices in the NT, CT, and ORG cropping systems of the USDA FSP, Beltsville, MD, 2001–2002

	Cropping system		
	NT	CT	ORG
Crop in 2001	Corn	Corn	Corn
Crop in 2002	Soybean	Soybean	Soybean
Winter cover crop 2000–2001	None	None	Vetch (killed by rolling; later tilled into soil)
Winter cover crop 2001–2002	Rye (killed with herbicide)	Rye (killed with disk)	Rye (mowed)
Fertilizer	Corn: starter 10–20-10; sidedress urea, ammonium nitrate Soybean: 0–0-60	Corn: starter 10–20-10; sidedress urea, ammonium nitrate Soybean: 0–0-60	None
Tillage and cultivation	None	Chisel plow, disk, field cultivator	Disk, field cultivator, rotary hoe, row cultivator
Pesticides	Paraquat, atrazine, S-metolachlor, glyphosate	Atrazine, S-metolachlor, glyphosate	None

abundance and/or species richness when tillage is reduced or eliminated (House and Stinner 1983, Brust et al. 1985, House and Parmelee 1985, Stinner and House 1990, Thorbek and Bilde 2003). Other studies have found no favorable effects from reduced tillage on total ground beetle abundance or species richness (Tyler and Ellis 1979, Cárcamo 1995, Belaoussoff et al. 2003). Because individual species respond differently to tillage due to habitat preferences, timing of management disturbances relative to life cycle, and/or effects on food resources (Clark et al. 1993, 1997), total carabid abundance and species richness may not be altered substantially even when changes in community composition have occurred. Moreover, the effects of tillage on ground beetles may be relatively short in duration and not detected in longer-term sampling intervals.

Most studies comparing carabid fauna in organic and conventional cropping systems have reported greater ground beetle abundance and species richness under organic management (Dritschilo and Wanner 1980, Dritschilo and Erwin 1982, Kromp 1989, 1990, Cárcamo et al. 1995, Pfiffner and Niggli 1996, Clark 1999, Shah et al. 2003). Interestingly, organic farming systems are often characterized by more frequent physical disturbance of the soil because cultivations, rather than herbicides, are used for weed management. However, organic systems don't have synthetic pesticide inputs and tend to use cover crops and organic amendments that may favor ground beetles directly by providing favorable habitat conditions or indirectly by supporting prey populations.

The USDA Farming Systems Project (FSP), located in Beltsville, MD, was established in 1996 to evaluate the sustainability of chisel-till, no-till, and organic cropping systems for the mid-Atlantic region of the United States (Cavigelli 2005). One of the objectives of the FSP is to understand the processes that influence ecological community structure, including that of soil macroinvertebrates. Here we report the findings from a comparison of ground beetle assemblages in organic, no-till, and chisel-till cropping systems in the FSP.

Materials and Methods

Study Site. The 16-ha study site is at the western edge of the Atlantic coastal plain in Beltsville, MD. The dominant soil types are Christiana (fine, kaolinitic, mesic Typic Paleudults), Matapeake (fine-silty, mixed, semiactive, mesic Typic Hapludults), Keyport (fine, mixed, semiactive, mesic, Aquic Hapludults), and Matapex (fine-silty, mixed, active, mesic Aquic Hapludults). The 30-yr average annual precipitation at the site is 1,110 mm, distributed evenly through the year.

Cropping Systems. In 1996, the FSP was established at the site, which had previously been managed without tillage since at least 1985. There were five cropping systems represented, arranged in four randomized complete blocks (Cavigelli 2005). The plots are laid out side by side within each block with no borders in between them. The dimensions of each plot are 9.1 by 111 m. We report on data collected from three of the cropping systems: (1) a chisel-till and (2) a no-till based 3-yr corn (*Zea mays* L.)–soybean (*Glycine max* L. Merr.)–wheat (*Triticum aestivum* L.)/soybean rotation, and (3) a 3-yr organic corn–soybean–wheat/hairy vetch (*Vicia villosa* Roth.) rotation. These systems were selected for the study because they had similar crop rotations but differed in management inputs and practices. Sampling was conducted in the same plots during the 2001 and 2002 cropping seasons. In 2001, the plots were in the corn phase of the rotations; in 2002, they were in the soybean phase of each rotation. Corn in all systems and soybean in the organic (ORG) plots were planted in 76-cm rows; soybean in the no-till (NT) and chisel-till (CT) plots were planted in 19 cm rows. A rye cover crop was planted using a no-till drill after corn harvest in all three systems.

A summary of management practices is presented in Table 1. The NT plots were never tilled but did receive herbicides before planting corn and after planting corn and soybean. The CT plots were tilled four times—once with a chisel plow, once with a disk, and twice with a field cultivator—before planting corn and twice with a disk before planting soybean. Weeds were controlled using herbicides after both crops were planted. The ORG plots were tilled two times, once with a disk and once with a field cultivator, before planting corn and cultivated four times after the corn was planted, twice using a rotary hoe and twice using a row cultivator. The ORG plots received no tillage before planting soybeans (soybeans were planted directly into a standing rye cover crop as in the NT plots; in ORG plots, rye was killed after planting soybeans using a flail mower), but they were cultivated four times after planting. The CT and NT plots were fertilized with mineral fertilizers in accordance with University of Maryland soil testing recommendations for both crops. Corn in ORG plots was supplied with N from the vetch cover crop. Chemical herbicides were applied to NT and CT plots according to University of Maryland weed management recommendations. No insecticides were used in any of the cropping systems during the 2 yr of the study.

Field Sampling and Data Analysis. Ground beetles were sampled in the 12 plots during the 2001 and 2002 cropping seasons using unbaited pitfall traps. Six pitfall traps (depth 95 mm by height 120 mm) were installed in a transect running down the center of each plot with 10 m between each trap. Locating the traps the maximum distance possible from the plot edges was intended to minimize edge effects. The traps contained propylene glycol and were maintained for 9–14 d during each of three sampling periods: May (spring); July (summer); and October (fall). The contents of the traps were preserved in 80% ethanol, sorted, and identified using keys in Lindroth (1961–1969) and Ciegler (2000). The specimens were also compared with reference specimens maintained at The Ohio State University and the National Museum of Natural History. Nomenclature follows Bousquet and Larochelle (1993) and Ball and Bousquet (2001).

The relative abundances (also referred to as activity densities when using pitfall traps) of common species and total ground beetles collected from each cropping system each year, the measured species richness (actual number of species collected) and estimated species richness of the carabid assemblages, and two indices of species diversity were compared statistically among the cropping systems using analysis of variance (ANOVA) followed by the Student–Newman–Keuls test when significant treatment effects were found ($P \leq 0.05$). Analyses were run on ranked data when violations in normality were found. Estimated species richness was calculated with EstimateS 7.5 (Colwell 2005) using several common methods: bootstrap, first-order jackknife, and Chao2 (Walther and Morand 1998, Toti et al. 2000). Species diversity was calculated using the Shannon and Simpson diversity indices as described in Brower et al. (1998).

Canonical variates analysis (CVA) was conducted on the 10 most common carabid taxa. To provide a sufficient number of samples for this analysis (number of samples must be sufficiently greater than number of variables for multivariate analyses), treatment was defined as cropping system plus year. Statistical comparisons among treatments were made using the Wilks λ test statistic from a multivariate ANOVA (MANOVA) (SAS Institute 2004).

Table 2. Carabid species collected from the USDA FSP site, Beltsville, MD, 2001–2002

Species	Number	Percent
Scarites quadriceps Chaudoir	655	28
Elaphropus anceps (LeConte)	409	18
Bembidion rapidum (LeConte)	318	14
Harpalus pensylvanicus (DeGeer)	185	8
Poecilus chalcites (Say)	136	6
Clivina impressefrons LeConte	111	5
Agonum punctiforme (Say)	86	4
Amara aenea (DeGeer)	83	4
Amara familiaris (Duftschmid) + *A. littoralis* Mannerheim	52	2
Bradycellus rupestris (Say)	45	2
Chlaenius tricolor Dejean	38	2
Clivina bipustulata (Fabricius)	24	1
Anisodactulus rusticus (Say)	24	1
Harpalus affinis (Schrank)	24	1
Stenolophus ochropezus (Say)	20	1
Acupalpus partiarius (Say)	18	1
Harpalus herbivagus Say	15	1
Anisodactylus sanctaecrucis (Fabricius)	14	1
Anisodactulus ovularis (Casey)	8	<1
Dyschiriodes globulosus (Say)	8	<1
Agonum octopunctatum (Fabricius)	8	<1
Harpalus erythropus Dejean	7	<1
Trichotichnus fulgens (Csiki)	7	<1
Colliuris pensylvanica (Linné)	6	<1
Cicindela punctulata Olivier	4	<1
Amphasia sericea (T.W. Harris)	3	<1
Anisodactylus caenus (Say)	3	<1
Patrobus longicornis (Say)	1	<1
Stenolophus comma (Fabricius)	1	<1
Amara pennsylvanica Hayward	1	<1
Total	2,313	100

Results

A total of 2,313 specimens, representing 31 species, were collected over the 2 yr of sampling (Table 2). All of the species except three, *Harpalus affinis* (Schrank), *Amara aenea* (DeGeer), and *Amara familiaris* (Duftschmid), are native to North America. Three of the species collected had not been recorded previously in Maryland according to Bousquet and Larochelle (1993): *Scarites quadriceps* Chaudoir, *Anisodactylus caenus* (Say), and *Harpalus affinis.* The eight most common species represented 87% of the total specimens collected and included *S. quadriceps, Elaphropus anceps* (LeConte), *Bembidion rapidum* (LeConte), *Harpalus pensylvanicus* (DeGeer), *Poecilus chalcites* (Say), *Clivina impressefrons* LeConte, *Agonum punctiforme* (Say), and *Amara aenea.* All of these species have been reported to be common in agricultural habitats of central and eastern North America (Esau and Peters 1975, Dritschilo and Erwin 1982, Ferguson and McPherson 1985, Barney and Pass 1986, Larochelle and Lariviere 2003, Larsen et al. 2003). Two species with relatively similar morphological characteristics, *Amara familiaris* and *A. littoralis* Mannerheim, were considered a single taxon for this analysis.

Table 3. Mean no. of the most common carabid species and total carabids collected per pitfall trap and measured species richness per plot from three farming systems of the USDA FSP, 2001

Carabids	Mean ± SEM			P
	NT	CT	ORG	
Scarites quadriceps	1.36 ± 0.44	1.60 ± 0.41	0.85 ± 0.20	0.46
Elaphropus anceps	0.30 ± 0.15	1.11 ± 0.56	0.89 ± 0.31	0.26
Bembidion rapidum	0.06 ± 0.04	0.06 ± 0.06	0.62 ± 0.40	0.16
Harpalus pensylvanicus	0.23 ± 0.08	0.08 ± 0.06	0.09 ± 0.06	0.40
Poecilus chalcites	0.02 ± 0.02	0.09 ± 0.04	1.42 ± 0.83	0.14
Clivina impressefrons	0.06 ± 0.04	0.14 ± 0.07	0.16 ± 0.03	0.43
Agonum punctiforme	0.09 ± 0.04	0.11 ± 0.03	0.62 ± 0.28	0.11
Amara aenea	0.09 ± 0.04b	0.11 ± 0.04b	0.64 ± 0.19a	0.01
Total carabid abundance	2.61 ± 0.63	3.93 ± 0.33	6.39 ± 1.81	0.10
Measured species richness	10.00 ± 1.47	11.00 ± 1.35	12.75 ± 0.65	0.08

Means with different letters within a row indicate significant differences, ANOVA, SNK, $P \leq 0.05$.

In 2001, only one of the eight most common species, *A. aenea,* showed a significant cropping system response. It was more abundant in the ORG system than in the other two systems. There were no significant differences in total carabid abundance or measured species richness (Table 3). In 2002, however, there were significant differences among cropping systems for four of the eight most common species, total carabids, and total species (Table 4). Three species, *B. rapidum, H. pensylvanicus,* and *A. aenea,* were significantly more abundant in the ORG system than in the other two systems, whereas *S. quadriceps* was more abundant in the NT system than in the ORG system. Two of those three species, *H. pensylvanicus,* and *A. aenea,* have been reported to feed on seeds (Larochelle and Lariviere 2003, Lundgren 2005) and may have been influenced by the greater food supply in the ORG system (Teasdale et al. 2004). The greater level of ground cover due to cover crops and weeds in the ORG system (J. R. Teasdale, personal communication) also may have had a positive influence on carabid abundance. The total number of ground beetles collected was greater in the ORG system compared with the other two systems, and the measured species richness was greater in the ORG compared with the CT system (Table 4).

A graph of the relationship between the mean cumulative number of species and the mean cumulative number of ground beetle specimens collected over the 2 yr shows the effect that sample size has on the direct measurement of species richness (Fig. 1). As the number of specimens collected increases, the number of species encountered also increases until an asymptote is eventually reached (Gotelli and Colwell 2001). In this study, the asymptote was not reached in any of the three systems, but because the ORG system had the greatest number of total carabids and the highest measured species richness in both years (Tables 3 and 4), it was apparently closest to this theoretical asymptote (Fig. 1). The bootstrap, first-order jackknife, and Chao2 methods allow for the estimation of the asymptotes and show very similar values for the three systems, ranging from ≈21 to 28 species (Table 5). These estimators showed no significant differences among the three cropping systems.

The Shannon and Simpson diversity indices showed the same general pattern among the three cropping systems during the 2 yr, but only in 2002 were there significant differences (Table 6). In 2002, the ORG system had a significantly higher Shannon index value compared with the other two cropping systems (F = 5.7, df = 2,6, P = 0.02) and a significantly higher Simpson index value compared with the NT system (F = 4.3, df = 2,6, P = 0.05). There were no significant differences between the NT and CT systems for either diversity index.

CVA showed a significant treatment effect (Wilks' λ, $P < 0.0001$), with canonical variates 1 and 2 ex-

Table 4. Mean no. of the most common carabid species and total carabids collected per pitfall trap and measured species richness per plot from three farming systems of the USDA FSP, 2002

Carabids	Mean ± SEM			P
	NT	CT	ORG	
Scarites quadriceps	3.25 ± 0.69a	1.97 ± 0.20ab	1.03 ± 0.06b	0.02
Elaphropus anceps	1.14 ± 0.10	1.39 ± 0.59	1.30 ± 0.22	0.91
Bembidion rapidum	0.63 ± 0.33b	0.72 ± 0.19b	2.61 ± 0.64a	0.007
Harpalus pensylvanicus	0.52 ± 0.34b	0.36 ± 0.10b	1.48 ± 0.57a	0.04
Poecilus chalcites	0.11 ± 0.07	0.09 ± 0.03	0.26 ± 0.12	0.11
Clivina impressefrons	0.16 ± 0.06	0.44 ± 0.12	0.70 ± 0.17	0.09
Agonum punctiforme	0.11 ± 0.05	0.11 ± 0.07	0.20 ± 0.08	0.63
Amara aenea	0.05 ± 0.03b	0.02 ± 0.02b	0.30 ± 0.11a	0.05
Total carabid abundance	6.76 ± 0.57b	5.60 ± 0.43b	9.31 ± 1.08a	0.01
Measured species richness	13.25 ± 1.03ab	12.00 ± 0.82b	16.00 ± 0.71a	0.05

Means with different letters within a row indicate significant differences, ANOVA, SNK, $P \leq 0.05$.

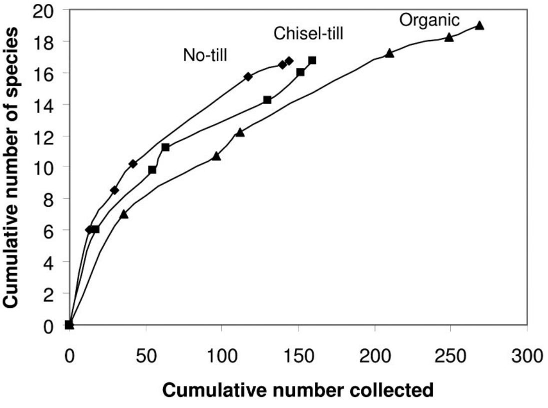

Fig. 1. Species accumulation curves showing the relationship between the mean cumulative number of ground beetle species collected and the mean cumulative number of specimens collected per cropping system over 2 yr of sampling at the USDA FSP, 2001–2002.

plaining 77 and 19% of total variability, respectively (Fig. 2). Canonical variates 1 and 2 were both significant (MANOVA, $P < 0.0001$). The mean value of canonical variate 1 was significantly different among all six system-by-year treatments except that the CT system in 2001 and NT system in 2002 were not different from each other (Table 7). Canonical variate 1 separated samples most strongly according to the numbers of *Bradycellus rupestris* (Say) and *P. chalcites* found in each sample and secondarily according to the numbers of *A. punctiforme, B. rapidum, C. impressefrons*, and *A. familiaris* + *A. littoralis* found in each sample (data not shown). Samples with high values of canonical variate 1 tended to have high numbers of *B. rupestris, A. punctiforme, B. rapidum*, and *C. impressefrons* and low numbers of *P. chalcites* and *A. familiaris* + *A. littoralis.* Mean values for canonical variate 2 were not different between the two conventional systems within a given year but all other treatment comparisons were significant (Table 7). Differences among treatments in canonical variate 2 were caused primarily by differences in the numbers of *A. aenea, H. pensylvanicus*, and *B. rapidum* found in samples. Samples with high values of canonical variate 2 had relatively high numbers of *H. pensylvanicus* and *B. rapidum* and relatively low numbers of *A. aenea.* Taken together, these CVA results show that, while almost all treatments differed from each other to some extent, the two conventional systems were more similar to each other than either was to the organic system in either year. In addition, differences among treatments were not caused by differences in the number of *S. quadriceps*, the most common species at the site.

Table 5. Estimated species richness of ground beetles in the NT, CT, and ORG cropping systems of the USDA FSP using three common estimation methods, 2001–2002

Method	Cropping system			*P*
	NT	CT	ORG	
Bootstrap	21.0	20.8	21.7	0.80
Jackknife	25.2	25.4	23.8	0.73
Chao-2	24.2	27.7	22.0	0.46

No significant differences among cropping systems, ANOVA.

Table 6. Shannon and Simpson diversity indices calculated for the ground beetle assemblages in NT, CT, and ORG cropping systems of the USDA FSP, 2001–2002

Index and year	Cropping system			*P*
	NT	CT	ORG	
Shannon 2001	0.72	0.68	0.91	0.10
Shannon 2002	0.73b	0.76b	0.93a	0.02
Simpson 2001	0.69	0.66	0.85	0.06
Simpson 2002	0.70b	0.75ab	0.83a	0.05

Means with different letters within a row indicate significant differences, ANOVA, SNK, $P \leq 0.05$.

Discussion

The quest to understand the effects of human-induced ecological disturbances is fundamental to developing practical, science-based approaches to managing ecosystems. This includes cropland, which covers ≈20% of the land area in the United States (Vesterby and Krupa 2001). No-till and organic production systems have emerged in recent decades as more environmentally sustainable alternatives to conventional, tillage-based production systems that are highly dependent on synthetic fertilizer and pesticide inputs and fossil fuels and are vulnerable to accelerated soil erosion. These alternative systems have been promoted because of shown benefits, including reduced pesticide use, fuel use, and soil erosion, and reduced potential for offsite environmental pollution. However, the environmental pros and cons of no-till and organic production systems differ.

According to The National Organic Program of the USDA, organic production systems "emphasize the use of renewable resources and the conservation of soil and water to enhance environmental quality" (The National Organic Program 2005). The primary distinction between organic and conventional crop production systems is that organic systems don't use synthetic fertilizers and pesticides. However, tillage is typically used for managing weeds and preparing soil as a seedbed. In contrast, the advantages of no-till management are derived from the lack of soil disturbance. These include increased soil organic matter and water infiltration and a reduction in soil erosion and fuel use (Hargrove 1990, Uri et al. 1999). Conventional synthetic herbicides are still a component of no-till systems, but the crop residues found on the surface may provide habitat and food for epigeic organisms, such as ground beetles, that play an ecological role in suppressing crop pests.

The objective of this study was to examine how ground beetles are influenced by different systems of annual crop production. Several common measurements and standard ecological indices and estimators were used, allowing the results to be compared with

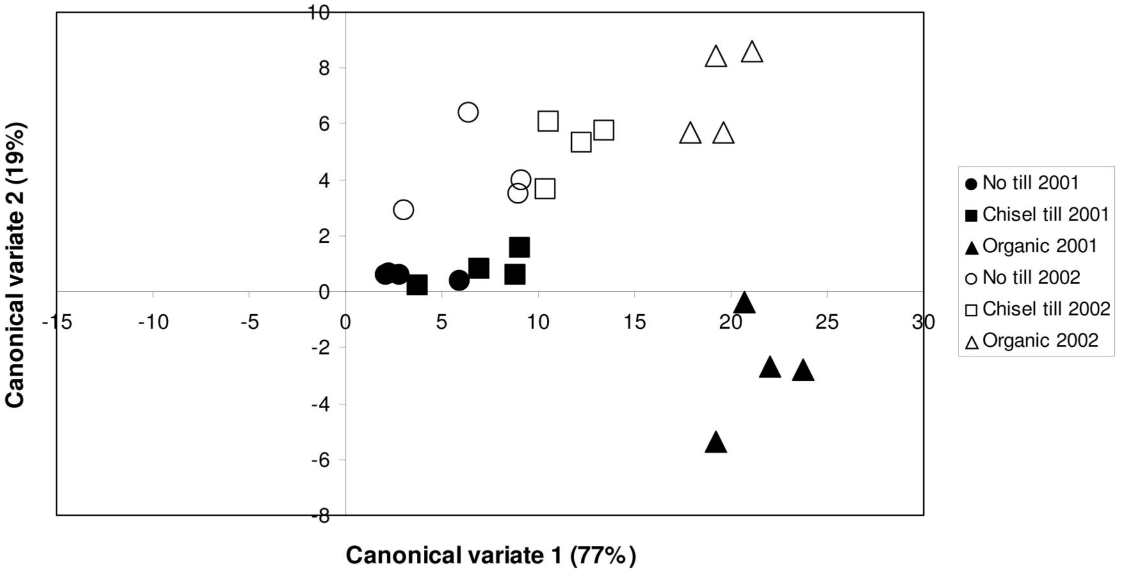

Fig. 2. Cropping system plots graphed on the first two canonical variates generated from the 10 most common species of the USDA FSP. Canonical variates 1 and 2 account for 77 and 19% of total variability, respectively. All system-by-year combinations are significantly different from each other according to canonical variate 1 except for chisel-till system in 2001 and no-till system in 2002. According to canonical variate 2, the organic system was significantly different from the chisel-till and no-till systems in both years ($P < 0.0001$).

other similar studies. In general, the differences observed between the ORG and CT systems are consistent with other studies comparing carabid assemblages in organic and conventional cropping systems (Clark 1999 and references therein). In 2002, the relative abundance, measured species richness, and species diversity were greater in the ORG than in the CT system. Similar patterns were observed in 2001, but no statistically significant differences were observed. Interestingly, the estimated total species richness did not differ between these two systems. The apparent inconsistency between the measured and estimated species richness values resulted from the greater number of ground beetles collected in the ORG system. This difference in relative abundance suggests a question for future study: do organic cropping systems have higher carabid absolute densities than conventional systems? Published comparisons of ground beetles in organic and conventional systems using pitfall traps and equal sampling effort usually report greater numbers of carabids in organic systems (Dritschilo and Wanner 1980, Kromp 1989, 1990, Cárcamo et al. 1995, Pfiffner and Niggli 1996, Clark 1999, Shah et al. 2003), but this sampling method precludes the separation of absolute density from activity. Further research could be aimed at addressing the question but methods for measuring carabid absolute densities are labor intensive (e.g., Frank 1971, Best et al. 1981, Brust et al. 1985, Clark et al. 1995).

Table 7. Mean canonical variates for the 10 most common carabid species for six cropping system-by-year treatments of the USDA FSP

Treatment	Canonical variate 1	Canonical variate 2
NT 2001	3.3e	0.6c
CT 2001	7.2d	0.8c
ORG 2001	21.4a	−2.8d
NT 2002	6.9d	4.2b
CT 2002	11.7c	5.2b
ORG 2002	19.4b	7.1a

Means with different letters within a column indicate significant differences, ANOVA, SNK, $P \leq 0.05$.

The finding of greater species diversity in the ORG system according to the Shannon and Simpson indices does differ from most other studies comparing carabids in organic and conventional cropping systems (Dritschilo and Wanner 1980, Cárcamo et al. 1995, Clark 1999, Shah et al. 2003). While the expectation may be that carabid assemblages would have higher diversity in organic farming systems because of the reduction in pesticide use and addition of organic amendments and cover crops, research has not shown this. Some researchers have debated the usefulness of these and other diversity indices for comparing ground beetles assemblages as well as the meaning of such numbers (Dritschilo and Erwin 1982, Jarošík 1991). Nevertheless, these tools provide a means of simplifying large, complex data sets on ecological communities for ease in comparison.

The relative similarity in the carabid assemblages of the NT and CT systems is somewhat surprising because some research has indicated that a reduction in soil disturbance by tillage and consequent accumulation of detritus in no-till and reduced tillage systems benefits ground beetles and other epigeic invertebrates (Stinner and House 1990). However, other studies using pitfall traps have shown that carabid abundance, species richness, and diversity are not influenced significantly by tillage (Ferguson and McPherson 1985, Belaoussoff et al. 2003), although the relative abundances of individual species may be (Clark et al. 1997).

The CVA based on the 10 most abundant species showed that the carabid assemblages in the three cropping systems were distinguishable from each other even in the relatively narrow plots of this field study where at least some carabid movement between plots would be expected. The differences observed between the treatments in this study probably reflect habitat preferences of individual carabid species or differences in food availability rather than direct positive or negative effects on isolated or semi-isolated carabid populations caused by management activities. The ORG system was found to be more different from the two conventional systems than the NT and CT were from each other. The regular use of cover crops in the ORG system, and its effect on the soil food web, may account for this difference. The assemblages within individual cropping systems over the 2 yr of the study also differed significantly according to the CVA, possibly caused at least in part by the different crops grown each year.

If a goal is to use ground beetles as indicators of ecological conditions or the effects of past disturbances, researchers need to consider whether community level attributes or indices, such as species richness, diversity, or some other multimetric index, are really useful or if instead focus should be given to individual species or groups of species based on knowledge of their biology and environmental sensitivities or preferences. In addition, the dependence on pitfall traps for sampling, although cost effective, has real limitations when comparing data from different treatments within a study or one study to another. Because no information on absolute densities can be gained from pitfall trap data, we know very little about the effects of human disturbances on the actual densities of ground beetle species, something that may be of profound importance when considering integrated pest management and biological control.

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