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RESPONSES IN ABUNDANCE AND DIVERSITY OF CORNFIELD CARABID COMMUNITIES TO DIFFERENCES IN FARM PRACTICES[1]

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Abstract. The response of carabid beetles to differences in tillage and chemical use was studied using four matched pairs of sites. Abundance and species richness were significantly different between treatments, but four commonly used measures of diversity were relatively insensitive indicators of change. It is suggested that the use of diversity indices in impact assessment is redundant or, when used with ground beetles, misleading.

Key words: Carabidae; corn fields; diversity indices; diversity measures; impact assessment; terrestrial environmental monitoring.

INTRODUCTION

Diversity measures, particularly in conjunction with a specific indicator community, have been popular in studies attempting to evaluate community changes. Cairns (1974) has argued that measures that reflect community structure, such as species diversity, are more valuable than abundance of indicator species in assessing environmental conditions. Presently, various indices of diversity (see Whittaker 1972, Peet 1974, and May 1975 for review and discussion) are the most accessible measures of community structure. Although it has been argued that diversity indices are of no value in comparing different communities (Hurlbert 1971), are "answers to which questions have not been found" (Poole 1974), and are inferior to other methods of data presentation (Green 1979), they are still in use for measuring changes resulting from perturbations (Cairns et al. 1972, Rosenberg 1972, Hendricks et al. 1974, Kempton and Taylor 1974, Briand 1975, Taylor et al. 1976, Bakelaar and Odum 1978, Vance 1979). In general, the lack of challenges to the conclusion that pollution decreases diversity (but see Cornell et al. 1976) has led to the frequent use of diversity indices in the burgeoning field of impact assessment.

It is this use of diversity measures in impact assessments to which this study is addressed. In the absence of a theoretical justification for one measure of diversity over another, the choice must be made on the pragmatic basis of utility. If one measure of diversity is a more sensitive and consistent indicator of community disturbance for a group of species than another measure, it can be usefully employed regardless of theoretical justification. Patrick (1949) and Cairns et al. (1972) demonstrated that certain aquatic communities could be effective and convenient indicators of aquatic pollution through the responses of measurements, such as diversity, of the community structure. Beetles of the family Carabidae hold considerable promise of being as effective indicators of perturbation in terrestrial communities (Freitag 1979) as diatoms are for aquatic communities, given that a suitable measure of response is established.

Carabids, or ground beetles, are easily sampled, occur in abundance in many habitats, respond rapidly and measurably to disturbance, and represent an integral part of ecosystem functioning by serving as important links between several trophic levels (Thiele 1977). They are a particularly important component of the litter fauna. Carabids have already received some use as indicators of perturbation. Freitag et al. (1973) related decreased abundance of ground beetles to the pollution effects of a paper mill. Lavigne and Campion (1978) reported increased numbers of carabids in grassland perturbed by addition of water and nitrogen. Soil insecticides have been shown to have positive and negative effects on ground beetles (Esau and Peters 1975, Gholson et al. 1978). Dritschilo and Wanner (1980) have demonstrated that differing farm management strategies result in changes in abundance and species richness of ground beetles.

This study examines the utility of several common indicators of community structure when used in conjunction with studies of ground beetles. The situation examined is one that may reasonably be expected to arise in impact work: identification of cryptic, short-term changes to the environment. The agricultural habitat used for the study had several advantages. It

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allowed for strict control of parameters that may have affected ground beetle densities, such as differences in soil types, microhabitats, or previous crops, but that were extraneous to the differences in farm management practices studied. It also represented the type of man-manipulated environment common to studies of environmental impacts, rather than the pristine environments ecologists normally study.

Methods

Four pairs of Midwestern grain farms were studied. Each pair differed in that one farm was managed in a conventional way, the other organically, without chemical fertilizers or pesticides. Conventional farmers also had a tendency to till less often but with heavier equipment. Soil types, location (all fields studied were adjacent to each other), crop type, previous crop, planting date, and variety of corn in the sites studied were identical for each farm in a pair. Each of the pairs of sites therefore represented identical habitats with two major differences: (1) the use of chemicals, and (2) tillage regimes. Two sites were located in northern Illinois, one in central Iowa, and the fourth in southeastern Iowa, resulting in the replication of treatment differences in four very similar but distinct habitats. The carabid fauna was distinct on at least three of the four pairs. The Illinois pairs had similar faunas.

Two of the pairs allowed the opportunity of an extra replicate. Site 2-O′ differed from 2-O by having corn planted on land that had been in corn the previous year (2-O had corn following beans) and site 4-C′ differed from 4-C by having been treated with herbicide but not chemical fertilizer (4-C was treated with both).

Ground beetles were collected in pitfall traps during April, June, and late September–October sampling periods. Only data obtained during the period of greatest abundance, June, is discussed in this study. Trapping efficiency was not affected by differences in microhabitat during the June period, as both sites in a pair appeared remarkably similar up to this time. Ten traps, fashioned after Morril (1975), were placed at 10-m intervals at each site, and beetles were removed every 24 h for two successive days at sites 1 and 2; three successive days at sites 3 and 4. Further specifics on the fields studied are given in Dritschilo and Wanner (1980).

The following data were obtained for each site:

carabid abundance (N), in mean number of specimens per trap day,

species richness (S), in number of species collected,

Shannon-Wiener diversity, expressed as

$$H' = -\sum_{i}^{S_i} p_i \ln p_i$$

Fisher's α, calculated from

$$S_T = \alpha \ln (1 + N/\alpha)$$

using an iterative technique, Berger-Parker dominance, expressed as

$$d = N_{max}/N_T, \text{ and}$$

Simpson-Yule index, expressed as

$$D = 1/\sum_{i}^{S_T} p_i^2$$

The equations used and definitions of terms are given in Southwood (1978).

Differences in abundance between sites in a pair were tested for statistical significance using Student's t on data transformed as $\sqrt{x+1}$ (due to zeroes in data). Differences in abundance between pairs and in species diversity measures were tested for statistical significance using Student's t for paired data.

Results

A complete list of species collected and abundance at each site is presented in Table 1. A mean per site of 70 carabid specimens (range 24–164) representing a mean of 8.6 species (range 6–18) was collected from the 10 sites (4 matched pairs and 2 extra replicates). In 3 of the 4 pairs, the number of beetles collected was significantly greater on the organic sites (Table 2). In the other pair, the organic site had a greater abundance of beetles, although not significantly so. Each of the organic sites also had a greater species richness (in terms of total species collected) than did the matched conventional site. Agreement between replicates of the same treatment (2-O and 2-O′ and 4-C and 4-C′) in terms of beetle abundance was excellent. Agreement with respect to species richness (11 vs. 11 and 8 vs. 6) was also good.

Also presented in Table 2 are values of four common measures of diversity: H', Shannon-Wiener Diversity, a much used and much maligned measured of the equitability of species abundance; α, the index of Fisher et al. (1943), a parameter of the logarithmic distribution of species abundance; d, simple dominance, an index preferred by May (1975); and D, the Simpson-Yule index, which is based on the probability of encounter between species. Data on abundance and species richness suggest that organic and conventional practices have differing effects on the carabid fauna. The effects, however, are not readily interpretable using several of the measures of diversity. Although species richness responded in a manner expected from sampling theory (sites with lesser abundance were less rich in species), the diversity indices were insensitive to some of the changes. In particular, H' and α failed to discriminate between sites 4-O and 4-C, in which abundance differed 7-fold and species richness 2-fold. Dominance appeared to be a relatively insensitive measure of change for the carabid community studied, as did the Simpson-Yule index, which is strongly influenced by the most abundant species. Possibly the

TABLE 1. Ground beetle species collected and abundances. Sites 1 and 2 represent 2 trap-days effort; sites 3 and 4, 3 trap-days. Site 2-O was planted with corn following beans, site 2-O′ with corn following corn. Site 4-C had been treated with both herbicide and chemical fertilizer, site 4-C′ with herbicide only.

Species	Sampling sites									
	1-O	1-C	2-O′	2-O	2-C	3-O	3-C	4-O	4-C	4-C′
Scarites substriatus Haldeman	0	0	1	7	0	0	1	7	4	3
Clivina impressifrons LeConte	3	9	0	3	0	1	0	3	0	0
Clivina bipustulata Fabricius	11	4	0	0	0	0	0	0	0	0
Patrobus longicornus Say	1	0	0	0	0	0	0	0	0	0
Bembidion americanum Dejean	2	0	0	0	0	0	0	0	0	0
Bembidion rapidum LeConte	25	22	0	0	2	1	12	3	0	0
Bembidion quadrimaculatum Linné	0	9	1	2	0	20	16	97	12	16
Elaphropous anceps LeConte	2	3	0	0	0	0	0	3	2	0
Agonum crenistriatum LeConte	1	0	0	0	0	0	0	0	0	0
Agonum subsericeum LeConte	3	0	0	0	0	0	0	1	0	0
Evarthus seximpressus LeConte	0	0	22	9	0	0	0	3	0	2
Evarthus sodalis LeConte	0	0	0	0	0	0	0	9	1	0
Pterostichus chalcites Say	46	43	1	9	9	58	2	32	2	0
Pterostichus lucublandus Say	3	1	9	12	5	13	3	3	0	1
Pterostichus stygicus Say	0	1	1	1	0	0	0	0	0	0
Abacidus permundus Say	0	0	0	0	0	0	0	2	0	1
Loxandrus sp.	0	0	1	1	0	0	0	0	0	0
Amara aenea DeGeer	1	0	0	0	0	0	0	1	0	0
Anisodactylus rusticus Say	0	0	1	0	0	0	0	0	0	0
Anisodactylus ovularis Casey	0	0	1	0	0	0	0	0	0	0
Anisodactylus sanctaecrucis Fabricius	2	3	1	2	7	3	0	0	0	0
Harpalus caliginosus Fabricius	0	0	0	0	0	0	0	0	0	1
Harpalus sp.	0	0	15	13	1	0	0	0	0	1
Stenolophus lecontei Chaudoir	10	2	0	0	0	0	0	0	0	0
Stenolophus comma Fabricius	8	2	0	0	0	0	0	0	0	0
Selenophorus granarius Dejean	1	0	0	0	0	0	0	0	0	0
Bradycellus sp. 1	0	0	0	0	0	1	0	0	0	0
Bradycellus sp. 2	1	0	0	0	0	0	0	0	0	0
Chlaenius pensylvanicus Say	1	0	0	0	0	0	0	0	0	0
Microlestes linearis LeConte	2	0	0	1	0	1	1	0	3	2
Total specimens	123	99	54	60	24	98	23	164	24	27
Total species	18	11	11	11	5	8	6	12	6	8

lack of sensitivity of H' to changes in the community is a result of the lack of change in dominance.

Although H' and d are nonparametric indices, both α and D (when $S > 10$) are influenced by the underlying distribution of species abundance (May 1975). It was not possible from the data to discriminate between the various species abundance models. However, the ability of a diversity measure to discriminate change due to environmental disruption can be more important than its fit to a model of species abundance (Kempton and Taylor 1974), as is true in this study.

In Table 3, the paired data are analyzed statistically. Although abundance and species richness both differ significantly between treatments, none of the indices of diversity do. The Shannon-Wiener Index, simple dominance, and the Simpson-Yule Index all have relatively little sensitivity to the community change suggested by abundance and species richness data. Fisher's α, preferred if the species abundance data truly reflects a log series, is more sensitive than the other indices but is less sensitive than simple abundance and species richness.

As a source for comparison, we have calculated the same indices for data on carabids given in a study of the pollution effects of a paper mill (Freitag et al. 1973). These are given in Table 4. Freitag and coworkers sampled beetles throughout a season (the data in Table 4 represent cumulative totals), rather than over a few days as in this study, and presumably had uncontrolled differences between sites unrelated to pollution. Their data did have a definite trend of decreasing carabid abundance with decreasing distance to the source of pollution. No trends were evident in the measures of diversity, with the possible exception of the Simpson-Yule index.

DISCUSSION

Diversity indices have been used for two different purposes: (1) to quantify the intrinsic structural diversity of communities or ecosystems, and (2) to assess structural changes to communities subject to disruption, particularly by pollution. It is the latter purpose that will be the subject of discussion.

Often environmental impact analysis consists of "before and after" studies or studies with only partial controls. Reliance on simple abundance in such stud-

TABLE 2. Ground beetle abundance and species diversity characteristics at paired sites. Significance levels are for comparisons of organic and conventional treatments of each site pair using Student's *t* test.

Site	Treatment	Abundance (*N*)		Species richness (*S*)	*H'*	α	*d*	*D*
1-O	organic	6.15	(N.S.)	18	2.06	5.8	0.374	4.92
1-C	conventional	4.95		11	1.72	3.2	0.434	3.86
2-O′	organic	2.70		11	1.61	4.2	0.407	3.65
2-O	organic	3.00	($P < .01$)	11	2.05	4.0	0.217	6.62
2-C	conventional	1.20		5	1.39	1.9	0.375	3.60
3-O	organic	3.27	($P < .01$)	8	1.20	2.1	0.592	2.43
3-C	conventional	1.17		6	1.30	2.1	0.457	2.95
4-O	organic	5.47		12	1.41	3.0	0.591	2.53
4-C	conventional	0.80	($P < .01$)	6	1.45	2.6	0.500	3.24
4-C′	conventional	0.90		8	1.43	3.8	0.592	2.63

ies is undesirable because numerous factors are known to affect abundance, particularly that of insects. Differences in abundance are as likely to result from uncontrolled variation in time or space as from treatment differences. Measures of structural changes maintain their popularity to the present because they offer the investigator the hope of a measure that is independent of sample size (Wilhm and Dorris 1968) and consequently of all the vagaries that afflict measures of abundance. However, hope turns out not to be reality. This experiment, due to the highly controlled nature of the environments studied and the opportunity for replication, afforded an excellent opportunity to test the utility of various indices of community structure. The conclusion is that the beetles responded to change; the diversity indices did not.

The data presented show that treatment differences resulted in marked differences in the carabid fauna. This finding is of some import to agriculture because carabids can serve as important agents of biological control (Thiele 1977). However, reliance on diversity indices would have resulted in the conclusion that the treatments studied left the carabid communities relatively unaffected. Without knowledge of the strict controls in this experiment, the differences in abundance might well have been credited to uncontrolled variables external to the treatment differences.

Stressed communities can respond to pollution through structural changes that do not result in loss of abundance. In some cases, as in marine communities around sewage outfalls, total abundance (in terms of biomass or individuals) increases. In such cases, simple dominance (*d* in this study) is thought by May (1975) and species richness (*S*) is thought by Poole (1974) to be the best measure of community diversity. In the carabid community studied, *S* was a consistent indicator of change; *d* was not.

The diversity indices discussed above are only a small subset of all extant indices. Southwood (1978) comments on their "explosive speciation." Little is to be served by examining other indices for the data presented here. Indeed, many diversity indices are interrelated (May 1975). Other promising approaches to analyzing changes in community structure, (cluster analysis is one example [Williams 1971]), result from a different philosophy of experimentation. Unlike the experiment described here, in which all parameters but treatment differences were identical for each pair, cluster analysis and other multivariate techniques are designed to make sense out of data in which most parameters are uncontrolled.

In conclusion, the use of diversity indices has been

TABLE 3. Statistical analysis of paired measures of diversity.

Diversity measure	Mean: Organic	Mean: Conventional	*t*-statistic (two-tailed)	df	Probability of chance difference
N	4.47	2.03	3.19	3	<.05
S	12.25	7.00	4.73	3	<.025
H'	1.68	1.46	1.21	3	<.4
α	3.7	2.4	2.01	3	<.2
d	0.444	0.442	0.030	3	>.5
D	4.12	3.41	0.823	3	<.4

TABLE 4. Ground beetle abundance and diversity at varying distance from a pollution source.*

Site (distance in yards†)	Abundance (total specimens)	Richness (Total species)	*H'*	α	*d*	*D*
900	245	17	2.42	13.2	0.241	9.0
1200	307	13	1.97	8.3	0.289	8.6
1650	593	16	2.17	8.7	0.248	6.8
2100	515	19	2.24	11.4	0.280	7.0
2700	901	17	1.93	8.3	0.403	4.4
10 miles‡	635	17	1.67	9.2	0.404	3.4

* Based on data found in Freitag et al. (1973).
† 1 yard = 0.9144 metres.
‡ 1 mile = 1.6 kilometres.

decried on a theoretical basis but has continued unabated in pragmatic studies of environmental impacts. This study offers no support, even on a pragmatic basis, for their use in evaluating changes in ground beetle community structure. Extrapolation from one taxon to another, or to an entire community, must be done with caution, but the results presented should make investigators suspect the use of diversity indices unless they have been proven valid for a particular use. In reviewing successful applications of diversity indices, Green (1979), however, found that other data presented in all such studies was sufficient to answer the questions posed, making the use of diversity indices a redundant and superfluous activity, even when successful.

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