In search of the best correlates for local organismal biodiversity in cultivated areas

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Based on a transect consisting of 19 identical trap stations in cultivated areas and seminatural habitats, the correlation of species numbers of higher taxonomic groups with total species numbers of flowering plants and arthropods per trap site was calculated. A total of 191 214 invertebrate specimens and 2221 species of plants and animals were analysed. Considering the value of the correlation coefficient R^2 as well as the effort for sorting and identification, a 'top twenty' list of indicator groups favours Heteroptera, flowering plants, Symphyta and aculeate Hymenoptera as the best choice for biodiversity evaluation. In general, flight traps rated better than pitfall traps. In most taxonomic groups, diversity indices such as the Shannon and the Simpson index were only weakly correlated with local species diversity.

Keywords: biodiversity; species diversity; correlation; indicator taxa.

Introduction

Gaston (1996a) in his recent review 'what is biodiversity?' finds that biodiversity can be seen as either a general concept (in the sense of an ecological paradigm), a trendy political construct (to enhance nature conservation efforts) or a measurable entity. Research on biodiversity evaluation has to tackle that last aspect, the scientifically controversial but nonetheless inevitable quest for some kind of a quantification of biological diversity. Publicly funded conservation programmes, environmental monitoring schemes and biological compensation programmes in cultivated landscapes should all include an element of monitoring in order to determine quantitatively the success or failure of the funded actions.

There is no doubt that biodiversity in the broadest sense of the Rio Convention (Johnson, 1993) cannot be measured as such. Numerous correlates and surrogates have been proposed in order to quantify biodiversity and compare its values in space and time (for a review see Gaston, 1996b). A rather conventional division of biodiversity breaks it down into genetic, organismic and ecological diversity (Harper and Hawksworth, 1994). A more functional classification separates biodiversity into compositional, structural and functional levels (Noss, 1990).

In practical terms, genetic diversity cannot be measured for whole communities or biotopes. It is not even clear whether intraspecific genetic diversity is correlated to species diversity in a given area, or to ecosystem diversity. However, ecosystem diversity or functional diversity can always be seen as a function of a particular set of organisms involved. Accordingly, ecosystem diversity or functional diversity are both reflected in

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organismic diversity. Given a set of ecosystems in a landscape, any additional ecosystem or functional complexity will inevitably be based on or reflected in additional species, and thus will broaden the overall genetic spectrum of living matter. Ecosystem diversity, habitat heterogeneity and functional diversity thus can be seen as surrogates rather than correlates of genetic diversity.

Other types of surrogates for biodiversity are indicator species for structurally diverse habitats, such as the capercaillie in Europe (Angelstam, 1992; Storch, 1993) or the spotted owl in North America (Thomas *et al.*, 1990). Surrogates are qualitative indicators of biodiversity, but do not necessarily correlate with local species diversity.

True correlates of biodiversity should show a statistically significant quantitative correlation to the total genetic spectrum of all organisms considered, be it on a local, regional, national or global level. Since biodiversity *per se* cannot be measured directly, correlates are the only measurable entity in any attempt to quantify and thus compare biodiversity.

Numerous taxa have already been proposed for measuring habitat quality or are assumed to reflect biodiversity in cultivated areas. Usually the choice is influenced by the taxonomic expertise of the people involved, by standard inventory and evaluation methods available, and often by the attractiveness of the taxa considered. The most sophisticated inventory and evaluation methods have been developed by vegetation scientists (Braun-Blanquet, 1964; Wildi and Orlóci, 1996). Since the effort for vegetation counts is extremely low compared to that of inventories for animal taxa, and since the replicability of vegetational data is much better, the flora is always the first choice when it comes to assessing biodiversity. But how well does it correlate with the species diversity of the fauna, which accounts for at least ten times more species in a given habitat than the flora? The purpose of the study presented here is to test species numbers or diversity measures of several faunistic groups and of flowering plants for their correlation with the total number of animal and plant species found at a given site.

Materials and methods

Arthropods make up about 65% of the species of all multicellular organisms (Hammond, 1992). In cultivated areas that percentage is likely to be even higher, therefore their speciose taxa are good candidates for biodiversity correlates. We analysed data from a large investigation on the dispersal of insects, spiders and other arthropods (Duelli *et al.*, 1992; Duelli and Obrist, 1995). The field work was conducted between 26 March 1987 and 22 October 1987 in the Limpach Valley, an elongated plain bordered by two hill-ranges in the Swiss central plateau. A 5 km long transect consisting of 19 identical trap stations was set up in an agricultural landscape. The transect started in two types of wetland (litter meadows, tall-sedge swamps with brushy areas; trap stations 1 and 2 in Table 1) and ended in a Mesobrometum bordering a mixed forest (trap station 19). In between, nine trap stations were placed in more or less improved grassland and seven in wheat fields. After the wheat harvest in late July, the traps in the wheat fields were changed to the nearest maize fields. As both crops included intensive treatment of the soil, the data were pooled to compare data collected in seminatural areas with those collected in agricultural areas on an identical seasonal time-frame. All traps were emptied weekly. The trap stations were always placed in the middle of meadows or fields (usually with surface areas of 1–2 hectares) and each consisted of an identical set of traps: 1 window (interception) trap with a vertical glass plate measuring 50 by 80 cm (Stöckli and Duelli, 1989), two yellow

Table 1. Numbers of species (upper numbers) and individuals (lower numbers) per trap site for all taxa completely or partly identified at the species level. Trap sites 1–19 arranged according to their position in the 5 km long transect

Group	Habitat									
	Total	wetland	wetland	grass	grass	grass	wheat/ maize	grass	wheat/ maize	wheat/ maize
	Site No									
		1	2	3	4	5	6	7	8	9
Araneae	169	78	83	63	48	33	30	37	35	25
	49462	955	1342	1395	3694	3249	1811	5988	2222	1555
Coleoptera	824	228	218	263	196	176	142	196	165	154
	68281	1573	1573	4533	4039	2899	2794	4615	5083	3468
Carabidae	98	48	44	45	37	36	30	36	36	34
	31412	210	470	2475	1966	1223	1624	2864	3658	1965
Coccinellidae	15	2	3	1	5	3	3	2	1	3
	142	2	4	2	5	5	5	3	8	7
Staphylinidae	204	74	60	68	52	45	32	46	53	43
	15957	437	485	803	846	831	549	751	600	770
Diplopoda	19	7	11	9	3	3	1	3	6	2
	1647	45	54	334	37	4	4	38	28	13
Diptera	440	143	119	156	110	117	82	91	107	103
	34743	1347	2435	2268	1480	2895	895	1571	1078	1710
Empidoidea	64	22	15	26	19	14	10	15	15	17
	2974	178	23	431	131	106	23	184	40	45
Syrphidae	68	33	26	20	21	17	6	10	13	9
	3336	519	191	131	229	236	32	141	68	62
Heteroptera	118	25	24	33	16	13	18	18	16	13
	2138	252	175	60	43	49	50	59	100	114
Hymenoptera	338	95	88	89	73	60	47	57	57	63
	23030	1777	1523	2050	521	847	206	450	1175	470
Formicidae	32	13	17	14	11	13	11	11	10	13
	12885	1231	1154	1495	75	334	84	126	1086	306
Aculeata excl.	202	56	49	50	42	30	26	29	34	33
Formicidae	7824	449	324	197	247	317	80	178	70	114
Symphyta	102	26	22	25	20	17	10	16	13	17
	2319	97	45	358	199	196	42	145	19	50
Isopoda	13	9	7	7	1			1	1	1
	6261	1953	1627	360	3			19	3	41
Neuroptera	16	4	2	3	4	2	2	2	2	4
	420	6	7	10	16	11	7	36	19	15
Psocoptera	31	7	5	8	3	5	6	6	6	5
	260	8	7	10	5	7	10	11	8	6
Saltatoria	19	10	9	13	7	6	1	7	4	3
	1208	77	48	195	81	47	28	64	39	26
Thysanoptera	32	14	13	14	15	13	11	15	14	15
	3729	337	151	128	310	110	82	274	195	136
Flowering plants	197	26	37	40	20	17	8	17	14	2
	—	—	—	—	—	—	—	—	—	—
Total	2221	647	618	699	496	445	348	450	428	391
	191214	8336	8944	11347	10229	10118	5887	13125	9951	7555

Table 1. (Continued)

Group	Habitat									
	grass	wheat/ maize	wheat/ maize	grass	grass	grass	wheat/ maize	wheat/ maize	grass	mesobro- metum
	Site No									
	10	11	12	13	14	15	16	17	18	19
Araneae	35	20	34	39	34	28	26	42	45	90
	3520	1921	2514	3643	4266	3130	2720	2315	1511	1711
Coleoptera	186	152	169	184	179	190	154	208	263	352
	2912	2919	3431	3513	3479	3176	3487	3032	5008	6747
Carabidae	33	32	36	30	33	30	29	29	39	38
	1245	1758	1844	1779	1462	1120	2208	1315	1908	318
Coccinellidae	3	3	1	1	3	3	4	4	6	5
	4	8	1	2	6	5	8	10	13	44
Staphylinidae	49	42	44	49	50	53	36	62	80	92
	750	550	741	925	935	977	560	794	1113	2540
Diplopoda	5	4	2	3	5		3	5	7	8
	87	73	33	15	37		35	45	134	631
Diptera	117	110	118	112	96	81	116	103	152	258
	2011	1698	1696	1485	2118	1546	1273	911	2353	3973
Empidoidea	20	21	23	19	19	10	22	23	22	42
	272	81	107	215	139	33	109	71	102	684
Syrphidae	16	6	8	12	14	14	8	6	28	35
	156	68	42	93	222	183	65	35	341	522
Heteroptera	17	13	18	14	12	17	13	19	37	68
	92	78	140	41	35	72	132	94	116	436
Hymenoptera	61	61	55	74	56	73	56	71	125	214
	1035	755	351	1617	766	902	313	901	2915	4456
Formicidae	11	14	12	17	14	14	11	16	22	26
	711	627	124	1271	92	277	161	408	1765	1558
Aculeata excl.	36	34	31	43	28	42	33	46	74	147
Formicidae	223	93	140	203	321	435	132	479	1041	2781
Symphyta	14	13	12	14	14	17	12	9	29	40
	101	35	87	143	353	190	20	14	109	116
Isopoda	3	1		1	2	2		2	2	4
	315	125		1227	2	41		2	131	412
Neuroptera	3	2	3	2	2	4	1	3	5	5
	32	25	15	22	25	42	12	17	80	23
Psocoptera	8	8	8	4	11	5	11	8	7	18
	20	20	18	9	15	9	19	14	17	47
Saltatoria	7	2	1	6	6	5	3	5	11	9
	162	2	3	114	50	52	9	19	105	87
Thysanoptera	12	10	15	13	10	13	10	9	15	17
	290	136	96	234	341	235	237	122	170	145
Flowering plants	16	11	8	24	11	13	9	18	36	51
	—	—	—	—	—	—	—	—	—	—
Total	471	395	432	477	424	431	402	493	707	1096
	10479	7753	8298	11921	11134	9205	8237	7472	12545	18678

water pans (21 cm diameter, 27 cm deep), two funnel pitfall traps (15 cm diameter; Obrist and Duelli, 1996) and one cup pitfall trap (7 cm diameter; Obrist and Duelli, 1996). All these traps are 'relative' sampling methods with a selective preference for active individuals. The trapping efficiency for different species depends on a variety of parameters (Adis, 1979), which makes it a prerequisite to use identical inventory methods in all habitats. In addition to the fixed trapping stations, sweep net samples were taken every two weeks. They consisted of five sets of 20 sweeps per field, taken with a standard entomology sweep-net (38 cm diameter).

With the help of numerous external experts, most of the taxa collected were identified at the species level. The aim was to include as many plant and animal species as possible in an assessment of local biodiversity. Some taxa are not well represented by the trapping methods used: Lepidoptera, Acari and other ground living arthropods, molluscs and all kinds of worms. For others it was not possible to find experts willing to go through such enormous numbers of specimens preserved in alcohol: Homoptera and Collembola. Likewise, only about half of the dipteran families were identified. A considerable number of staphylinid species had to be excluded from the analysis, because the large subfamily Aleocharinae could not be identified with certainty to the species level. Furthermore, for methodological reasons, all vertebrates were excluded from the study. As their contribution in terms of numbers of species is irrelevant for a quantitative assessment of organismic local biodiversity, this seems justified.

Flowering plants were identified by standard vegetational inventories up to a distance of 10 metres from the centre of the trap station. Individuals of plants were not counted. Therefore, in some analytical cases, the vegetation data had to be treated differently from those of animals.

To estimate the contribution of all taxa considered, relative to all organisms present at a given site or location, their percentage relative to the numbers of species known to occur in Switzerland was calculated. All other taxa, not considered in the present study for whatever reasons, were also rated in terms of numbers of species known to occur in Switzerland. From this rather crude approximation, all taxa considered were estimated to contribute close to 50% of all multicellular plants and animals present in the sampled habitats.

Results

A total of 191 214 animal specimens and 2221 species of plants and animals were included in the analysis (Table 1). The highest species number per trap station was found in the semi-dry meadow (Mesobrometum; 1090 species), followed by the two wetlands, a fertilized grassland close to the forest edge (No. 9 in Table 1), and another grassland bordering the wetlands (No. 3 in Table 1). Minimum overall biodiversity was found in a wheat/maize-field (No. 6 in Table 1) in the centre of the transect, i.e. at maximum distances from the seminatural habitats at the two ends of the transect.

For numerous taxonomic groups at various levels (from orders to families), the species numbers for each of the trap stations were plotted against the total number of organisms recorded at these stations (Fig. 1). Linear regressions were calculated and tested for their correlation coefficient R^2 . Table 2 shows the taxa or groups of taxa considered in that analysis, sorted according to the best fit (R^2 of N sp.). The Coleoptera made up 37% of all species. It is therefore not surprising to see that this order, with the highest species number,

Figure 1. Examples of linear correlation in higher taxonomic groups between their species numbers per trap site and the total number of identified species of organisms recorded with standardized methods at the 19 trap sites.

also shows the best correlation, due to their contribution to the overall species diversity. More of a surprise is the highly significant correlation of the Heteroptera, considering their relatively low number of species and, even more so, their small number of individuals. Almost at the very bottom of the list we find the Carabidae, by far the most frequently used arthropod group in all kinds of assessments of habitat quality.

A closer look at the family level in the insect orders with the best correlation, shows that for the 17 families recorded within the Heteroptera, the best correlation was found for the Lygaeidae ($R^2 = 0.902$). Pentatomidae (0.747) and Anthicoridae (0.730) were still highly significantly correlated ($p \leq 0.0001$), but most other families contained too many ubiquitous grassland species (Miridae; 0.690), or were too rare to be significant on their own. Still, taken as a whole order, they all contributed to the excellent correlation coefficient of 0.927. Within the aculeate Hymenoptera, the highest correlation was found for the Sphecidae (0.884), the Colletidae (0.808) and the Megachilidae (0.800), whereas both the Vespidae (0.196) and the Apidae (0.193) were not correlated at all. The best three families combine predators (Sphecidae), generalist flower visitors (Colletidae) and flower specialists (Megachilidae). Of the eight families of Symphyta recorded, the Tenthredinidae (0.855) were absolutely dominant. The other seven families were too rare or too specialized to yield a significant correlation, but together they were able to slightly increase R^2 up to 0.874.

Table 2. Correlation of species numbers (N_{sp}), Shannon and Simpson indices of identified higher taxa, with the total species numbers per trap site, sorted according to the correlation coefficient R^2 ; numbers of species and individuals (N_{ind}) per group are also expressed in % of the total catch (individuals were not counted in plants)

Tax. group	correlation coefficient R^2			N_{sp}	% sp.	N_{ind}	% ind
	N_{sp}	Shannon	Simpson				
1 Coleoptera	0.958*	0.269	0.172	824	37.1	68281	35.7
2 Hymenoptera	0.930*	0.080	0.045	338	15.2	23030	12.0
3 Heteroptera	0.927*	0.663*	0.509*	118	5.3	2138	1.1
4 Hym.-Aculeata ^a	0.903*	0.001	0.070	202	9.1	7824	4.1
5 Diptera	0.893*	0.247	0.385*	440	19.8	34743	18.2
6 Symphyta	0.866*	0.406*	0.271	102	4.6	2319	1.2
7 Flowering Plants	0.849*	—	—	197	8.9	—	—
8 Staphylinidae	0.845*	0.265	0.133	204	9.2	15957	8.3
9 Epig. predators ^b	0.818*	0.502*	0.354*	471	21.2	96831	50.6
10 Araneae	0.719*	0.577*	0.506*	169	7.6	49462	25.9
11 Aphidophaga ^c	0.712*	0.496*	0.096	99	4.5	3898	2.0
12 Syrphidae	0.700*	0.401*	0.244	68	3.1	3336	1.7
13 Formicidae	0.668*	0.224	0.434*	32	1.4	12885	6.7
14 Empidoidea	0.645*	0.003	0.003	64	2.9	2974	1.6
15 Raphidioptera	0.597*	—	—	2	0.1	2	0.0
16 Saltatoria	0.498*	0.334	0.225	19	0.9	1208	0.6
17 Diplopoda	0.482*	0.069	0.001	19	0.9	1647	0.9
18 Neuroptera	0.377*	0.437*	0.161	16	0.7	420	0.2
19 Psocoptera	0.364*	0.168	0.041	31	1.4	260	0.1
20 Mecoptera	0.317	—	—	1	0.0	15	0.0
21 Carabidae	0.311	0.360*	0.405*	98	4.4	31412	16.4
22 Thysanoptera	0.300	0.135	0.081	32	1.4	3729	2.0
23 Isopoda	0.258	0.146	0.028	13	0.6	6261	3.3
24 Coccinellidae	0.118	0.188	0.019	15	0.7	142	0.1
25 Megaloptera	0.000	—	—	2	0.1	18	0.0
Total				2221		191214	

* highly significant ($p \leq 0.01$).

^a without Formicidae; ^b Araneae, Carabidae, Staphylinidae; ^c Neuroptera, Coccinellidae, Syrphidae.

In a second run, the most commonly used biodiversity indices (Shannon and Simpson Index) were tested for their correlation with overall species numbers (Table 2). Only eight Shannon and six Simpson indices correlated highly significantly ($p \leq 0.01$). Based on diversity indices, the Heteroptera showed the best correlation. Interestingly, for the Carabidae, the Simpson and the Shannon indices rated better than the species numbers, while most other groups correlated better in terms of species numbers.

In most field investigations, only one or two collecting methods are used. If the data in our analysis are separated into flight trap data (window traps and yellow pans) and pitfall trap data (funnel traps and cup traps), the correlations are usually much better for the flight trap data (e.g. all Coleoptera, Araneae), even though the pitfall traps often collect many more individuals (Table 3).

Table 3. Correlation values as in Table 2, but separated for collecting methods

Group	R ²	N species	N individuals	Trap type
1 Hymenoptera	0.913*	326	11351	flight
2 Hym.-Aculeata ^a	0.901*	200	7717	flight
3 Diptera	0.893*	440	34743	flight
4 Coleoptera	0.872*	692	30141	flight
5 Heteroptera	0.870*	114	1479	flight
6 Symphyta	0.819*	96	2277	flight
7 Aphidophagac	0.712*	99	3898	flight
8 Epig. predators ^b	0.710*	230	10621	flight
9 Syrphidae	0.700*	68	3336	flight
10 Empidoidea	0.645*	64	2974	flight
11 Araneae	0.643*	120	48412	pitfall
12 Araneae	0.616*	54	653	flight
13 Formicidae	0.611*	25	11530	pitfall
14 Raphidioptera	0.597*	2	2	flight
15 Staphylinidae	0.581*	135	9042	flight
16 Formicidae	0.556*	28	1355	flight
17 Saltatoria	0.554*	12	403	pitfall
18 Epig. predators ^b	0.540*	331	85570	pitfall
19 Diplopoda	0.465*	19	1647	pitfall
20 Carabidae	0.438*	41	926	flight
21 Neuroptera	0.377*	16	420	flight
22 Coleoptera	0.369*	228	37897	pitfall
23 Psocoptera	0.364*	31	260	flight
24 Staphylinidae	0.340*	127	6672	pitfall
25 Isopoda	0.334*	13	6261	pitfall
26 Carabidae	0.180	84	30486	pitfall

Flight traps: window interception traps and yellow water pans; pitfall traps: funnel traps and cups.

* highly significant ($p \leq 0.01$).

^a without Formicidae; ^b Epigeous predators: Araneae, Carabidae, Staphylinidae; ^c Neuroptera, Coccinellidae, Syrphidae.

In order to quantify and evaluate site specific biodiversity, the choice for one or several groups of plants and animals, and for a particular inventory method, cannot be based only on the best correlative value R^2 . In every-day biodiversity assessments for nature conservation, a compromise has to be found between effort and yield, i.e. between the time and money spent to collect, sort and identify the samples, and the predictive value (R^2) obtained. Figure 2 shows the R^2 -values of all the taxa, collecting methods and indices which yielded highly significant ($p \leq 0.01$) correlations, plotted against the effort for sorting and identification, based on the approximation, generalized from our experience, that all taxa require about the same time for determination (20 specimens per hour). Accordingly, the upper left corner of Fig. 2 contains the optimal combinations of yield and effort. For a detailed rating in search of the best choices for biodiversity correlates, a line was drawn connecting diagonally lower left ($R^2 = 0$, N ind. = 0) with upper right ($R^2 = 1$, N ind. = 100 000), describing a linear increase of yield with effort (Fig. 2 inset). The distance of data points from this line indicates the nonlinear deviation from this linear

Figure 2. Combination of yield (correlation coefficient R^2) and effort (time for sorting and identification) for various groups, collecting methods and indices, which all showed a highly significant ($p \leq 0.01$) correlation with local species diversity. (a) Effort in linear scale illustrating the graphical calculation (distances d_1 – d_{20}) of the 20 optimum combinations between effort and yield ('top twenties', see Table 4). (b) Effort is shown in log scale for better visibility. Numbers behind annotations indicate ranks 1–20 (see Table 4), lower ranking data are not numbered and are annotated in fine print.

increase. The largest deviation or distance (d_1 in Fig. 2, inset) is interpreted as the most economic choice for a true correlate of site specific or local biodiversity. To make plants comparable in this plot, we estimated a period of 25 hours for a thorough vegetation mapping of all 19 sites, which is time-equivalent to the identification of 500 arthropods.

Table 4 lists the 'top twenty', optimizing effort and yield. Heteroptera, either collected with all trap types or with only flight traps, are clearly the best choice for a correlate. The fact that they are immediately followed by the flowering plants confirms that plants indeed make an excellent correlate of overall biodiversity, mainly because of the comparatively low effort necessary to reach a reasonably good correlation. Fourth rank the Symphyta, a group of mainly herbivorous Hymenoptera which are rarely used in biodiversity assessments. Flight traps in the 'top twenty' list are even more superior to pitfall traps as compared to Table 2, because of the lower numbers of individuals caught. This is especially striking in a group such as the spiders, which is usually collected in standardized pitfall traps; while the spiders in the flight traps, with only 653 specimens and 54 species, rank at position 14, the almost 50 000 spiders from 120 species in the pitfall traps, with an only slightly higher correlation than the flight traps, would only appear at position 37 in Table 4. The best correlation of a Shannon index, at position 12, is again held by the Heteroptera. Staphylinid beetles reach position 10, but only if collected with all trap types. In this group, both pitfall and flight traps accounted for separately, yield only low correlation values. Carabidae do not even appear on the 'top twenty' list.

Table 4. List of the 'top twenty' indicator groups, combining high correlation (yield) with minimum effort, according to measured distances d in Fig. 2a

Group	R^2	N species	N individual	correlate
1 Heteroptera	0.927	118	2138	all traps
2 Heteroptera	0.870	114	1479	flight traps
3 Flowering plants	0.849	197		
4 Symphyta	0.866	102	2319	all traps
5 Hym.-Aculeata ^a	0.901	200	7717	flight traps
6 Hymenoptera	0.913	326	11351	flight traps
7 Symphyta	0.819	96	2277	flight traps
8 Hymenoptera	0.930	338	23030	all traps
9 Staphylinidae	0.845	204	15957	all traps
10 Aphidophaga ^c	0.712	99	3898	flight traps
11 Syrphidae	0.700	68	3336	flight traps
12 Heteroptera	0.663	118	2138	Shannon all traps
13 Empidoidea	0.645	64	2974	flight traps
14 Araneae	0.616	54	653	flight traps
15 Epig. predators ^b	0.710	230	10621	flight traps
16 Coleoptera	0.872	692	30141	flight traps
17 Saltatoria	0.554	12	403	pitfall traps
18 Diptera	0.893	440	34743	flight traps
19 Formicidae	0.556	28	1355	flight traps
20 Formicidae	0.668	32	12885	all traps

^awithout Formicidae; ^bEpigeous predators; Araneae, Carabidae, Staphylinidae; ^cNeuroptera, Coccinellidae, Syrphidae.

Discussion

Biodiversity, treated as a 'measurable entity' (Gaston, 1996a), is a relative measure. Natural habitats can be characterized by very low site specific species numbers (raised bogs, tundra, etc.), but still are very important for national or global biodiversity by contributing specialized organisms, which cannot be found elsewhere. Thus, higher biodiversity in terms of species numbers is not inherently preferable or 'better' for nature conservation in natural habitats. However, in temperate regions and especially in cultivated areas and other habitats strongly influenced by human activity, biodiversity can be seen as an indicator of environmental quality.

In most cases in practice, biodiversity is measured in the form of species diversity, although it is obvious that other standard units of biodiversity such as genetic and phylogenetic divergence are not objectively reflected in comparing species numbers (Heywood, 1995). But as long as no better practical and straightforward methods of quantifying biodiversity are available, people involved in biodiversity evaluation and monitoring programmes will have to go on counting and comparing species numbers in space and time. To do so, a strict standardization of inventory methods and of the evaluation procedure is a prerequisite.

Since the whole genetic spectrum of organismic diversity cannot be measured even on a small surface for everyday use, e.g. for environmental impact studies, the best correlates have to be found, while keeping the efforts for sampling and identification to an affordable minimum.

The results of the present investigation show that many taxonomic groups show a highly significant correlation of species numbers with overall site specific species diversity. But the groups scoring best are not the groups which are commonly used in assessments of habitat quality in cultivated areas. Spiders, grasshoppers, staphylinid beetles, and particularly the notorious carabids, do not seem to correlate very well with local biodiversity. Even worse are the performances of the most popular diversity indices used: the Shannon and the Simpson index.

We have to keep in mind, however, that in agricultural investigations the goal of an evaluation is mostly the value for biological control, and not biodiversity *per se*. To enhance antagonists of agricultural pests, increasing their abundance is basically more important than increasing their species numbers, unless ecological resilience in view of imminent environmental change is regarded. Another kind of evaluation, where higher biodiversity is not always the primary goal, consists in a comparison of numbers of endangered species for conservation values. The correlation between the number of Red List species and other forms of rapid biodiversity assessment with local alpha-diversity in our data set will be treated elsewhere. The search for taxonomic groups showing optimum correlation with local biodiversity is particularly helpful in view of recently proposed methods to reduce the effort and costs by using higher-taxon richness (Williams and Gaston, 1994), taxonomic relatedness of single speciose groups (Williams *et al.*, 1991) or morphospecies as surrogates for species (Cranston and Hillman, 1992; Oliver and Beattie, 1996).

Considering effort and yield, the Heteroptera give the best correlate of biodiversity, either on plain species numbers or as diversity indices. The reason for this excellent correlation is likely to be based on their trophic variability: many species are plant feeders, some are specialists, some generalists and others are predators. Moreover, evenness among

species was high in our samples, with generally low numbers of individuals. Hymenoptera are successful as well, in this study represented by the Symphyta and Aculeata. Unfortunately, the speciose parasitoid wasps, for which it is difficult to find experts for the identification of all the families, could not be included in this study.

Whether our results for local biodiversity can be generalized for other habitats in cultivated landscapes, or even extrapolated into natural areas with much higher structural diversity, has to be left for further investigations. The requirement for identical inventory methods and equally high efforts for collecting and identification in all the trap locations limits the possibility for a comparison with already published results.

In general, flight traps (here: window interception traps and yellow water pans) are doing much better than pitfall traps. This is astonishing, since pitfall traps sample much larger numbers of individuals, much more locally than flight traps. But, obviously, the taxa dominating the catches in the pitfall traps depend more on the type of cultivation than on site specific biodiversity. They are mostly predatory and polyphagous, hence comprise a far less variable trophic spectrum compared to the arthropods collected in flight traps.

To assess organismal biodiversity in cultivated habitats in temperate regions, we therefore recommend the use of flight traps (window traps and yellow pans) and the comparison of species numbers of higher plants, Heteroptera and Symphyta or aculeate Hymenoptera.

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