

EVALUATING BIODIVERSITY THROUGH FUNCTIONAL GROUPS: A COMPARISON OF FUNCTIONAL GROUPS AND BIODIVERSITY MEASURES

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INTRODUCTION

Quantification of biodiversity is crucial to development of policy aimed at the conservation of flora and fauna, and ecologists are therefore under pressure to arrive at an agreed mode of evaluating biodiversity (Hunter 1996). However, difficulties arise in defining biodiversity because it is studied at different levels, usually distinguished as the genetic, species, community and landscape levels, each of which constitutes a different facet of the subject (Noss 1992). Where a decision is made to focus on the community level, further problems arise in quantifying biodiversity. Communities are to a greater or lesser extent multispecific, and taxonomic and time constraints prevent the identification of all species present. This has resulted in the adoption of indicator taxa and functional groups as a pragmatic means of approximating community biodiversity (McLaren *et al.* 1998; Williams 1998). Some studies have found relationships between functional groups, for example butterfly and vegetation communities, and have suggested that a single functional group may be used as an indicator of landscape-scale ecological processes (Oostermeijer and van Swaay 1998; Negi and Gadgil 2002). However, it has been argued that such functional groups are often selected on the basis of popular attractiveness and ease of survey, rather than on ecological criteria such as importance to ecosystem functioning (Hunter 1996), and that the outcomes of biodiversity quantification based on such indicators may relate more to functional group choice than to attributes of the community (Walker 1989).

If it is decided to attempt quantification of the biodiversity of a community through a survey of indicator functional groups, then a method of quantification must be selected. Many such methods have been suggested, but perhaps the most frequently adopted methods are (1) to count the number of species and (2) to combine the number

of species and the distribution of individuals among species within a diversity index (Magurran 1988).

This short communication aims to provide information relevant to answering the following two questions: Does the choice of indicator functional group affect the estimation of biodiversity? Does the choice of quantification method affect the estimation of biodiversity?

METHODS

To assess the effect on biodiversity of a range of farming practices in County Down, Northern Ireland, surveys of flora and fauna were carried out in 1971–2 in five lowland farmland blocks, each approximately 18ha in extent (Moles 1974) and representative of a > 4km² landscape unit. During the surveys, fields in two blocks (G1 and G2) were under permanent grass, another two blocks (T1 and T2) were planted with mixed crops, including cereal, root and green crops, and the fifth block (M1) contained a mixture of grass (38% by area) and tilled (62% by area) fields. Surveys were undertaken of six functional groups: Breeding birds, Wintering birds, Butterflies, Moths, Woody plants and Forbs (Moles 1974). Selection of functional groups was based on (a) the assumption that to facilitate interblock comparisons, indicators should represent a wide spectrum of genetic diversity, and (b) the pragmatic requirement that they be quickly and reliably identifiable to species.

For Breeding birds, five counts per block were carried out between mid-May and the end of June, each count lasting 3h and starting 1h after dawn on days without mist, rain or strong winds. Over-flying individuals were not counted. The location of each individual was recorded on maps. The presence of breeding pairs was established through comparison of the five count maps, and territory boundaries were estimated on the basis of observation of occupied nests, juveniles, singing

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males, fighting, and carrying of nest material and food. Where individuals were recorded at similar locations on four or five counts, or where nesting was confirmed, this was accepted as evidence that a pair was resident. Where individuals were recorded at similar locations on two or three counts, it was considered likely that a pair was present, and a single individual (half-pair) was taken to be resident. (This occurred most frequently near block boundaries.) Summing individuals in pairs and half-pairs per species per block provided a measure of abundance.

Counts of Wintering birds in each block were undertaken between mid-January and the end of February on five days without continuous rain or strong wind. Counting was undertaken for 3h on a standard transect following all field boundaries. Individuals in both fields and field boundaries were counted, but over-flying individuals were not. The abundance of a species in a block was calculated by averaging the three highest day count totals for that species.

Counts of Butterflies in each block were undertaken on eight days on which butterflies were flying between May and September. Individuals were netted, identified and temporarily held in a box until no further individuals were visible in the block. Some individuals flying high or over crops were not netted but were included in counts. To provide a measure of abundance for each species in each block, the maximum numbers of individuals counted in each of the five months were summed.

Moths (Macrolepidoptera) were sampled using portable light-traps with ultraviolet light sources (23cm, 6W Actinic fluorescent tubes powered by 12V batteries) set on holding boxes. Between July and September, simultaneous trapping in each block occurred for 3h at a time on nine nights without mist, rain or strong wind. Not all moths are attracted to light, and the families Noctuidae and Geometridae provided the majority of trapped individuals. Trapped individuals were killed because identification often necessitated comparisons with reference collections at the Ulster Museum, Belfast. To provide a measure of abundance per species per

block, total numbers of individuals trapped during nine nights were summed.

Woody plant species form three-dimensional structures that include trees, bushes, hedges and scrub. A single survey per block of these structures aimed to estimate the volume of each constituent species. The total volume of each tree was estimated. On the basis of measurement of a sample of bushes, average volumes were derived (bushes > 4m high: 20m³; 2–4m: 8m³; < 2m: 2.7m³). To facilitate surveying, hedges and scrub patches were divided into units of 20m³. For all trees and bushes and each unit of hedge and scrub, the volume (in m³) of constituent species was estimated with the aid of a measuring tape. The abundance per species per block was calculated by summing volumes in trees, bushes and units of hedge and scrub.

A 1m² quadrat was used in sampling Forbs (non-gramineous herbaceous flowering plants) to calculate percentage frequencies based on presence of aerial parts. Surveys were undertaken twice monthly between May and September. Sampling was confined to linear habitats at field boundaries (grass headlands, drainage ditches, rough and open ground, and hedge and scrub bases). At all field boundaries in grassland fields, strips 1m wide were sampled. Quadrats were placed parallel to field boundaries at 5m intervals. Each component field-boundary habitat > 1m wide was surveyed: for example, a grassland headland, drainage ditch and hedge base present at a field boundary were each sampled separately. To provide a measure of abundance per species per block, percentage frequency values were calculated for all quadrats (that is, all habitats and ten surveys aggregated).

Biodiversity per block within functional groups was quantified on the basis of (a) number of species and (b) species diversity. Different diversity indices have varying properties and limitations (Magurran 1988). The purpose of this work was to compare floral and faunal groups that in some cases were represented by many species and individuals and in other cases by few species and individuals. Further, different methods were used to survey functional

Table 1—Biodiversity scores for farmland blocks.

	<i>Breeding birds</i>		<i>Wintering birds</i>		<i>Butterflies</i>		<i>Moths</i>		<i>Woody plants</i>		<i>Forbs</i>	
	<i>Sp. no.</i>	<i>HB</i>	<i>Sp. no.</i>	<i>HB</i>	<i>Sp. no.</i>	<i>HB</i>	<i>Sp. no.</i>	<i>HB</i>	<i>Sp. no.</i>	<i>HB</i>	<i>Sp. no.</i>	<i>HB</i>
G1	25	2.7	19	2.1	13	1.9	57	3.1	30	1.9	116	3.6
G2	22	2.4	18	1.9	11	1.8	44	2.8	27	1.9	111	3.5
T1	25	2.5	27	2.4	12	1.6	45	2.8	26	1.9	104	3.5
T2	13	2.2	14	2.0	10	1.4	54	2.7	26	1.8	89	3.3
M1	16	2.3	23	2.2	9	1.5	44	2.5	30	1.5	102	3.2

Sp. no. = Number of species recorded; HB = Brillouin diversity index.

groups—in some cases, the entire community was described (e.g. Breeding birds), whereas in others, non-random sampling was employed (e.g. Moths). Given this, the most appropriate diversity index is the Brillouin index (HB), a form of the information index described by Pielou (1969) and reviewed by Magurran (1988). The Brillouin index is expressed in the equation

$$HB = \frac{\ln N! - \sum \ln n_i!}{N}$$

where n = the abundance of a species and N = the abundance of all species in the assemblage.

RESULTS

In relation to number of species and diversity indices per functional group per block (Table 1), two points are noteworthy. First, HB scores within groups differed little: very small differences in value were associated with relatively great differences in species number. Second, with the exception of Wintering birds and Woody plants, all functional groups and both measures indicated that Block G1 had the greatest biodiversity (though jointly with Block T1 in the case of Breeding birds/number of species), but there was little agreement in relation to the least diverse block.

Table 2—Between block correlations (Pearson) in functional group biodiversity measured by number of species, with *P*-values in italics.

	<i>Breeding birds</i>	<i>Wintering birds</i>	<i>Butterflies</i>	<i>Moths</i>	<i>Forbs</i>
Wintering birds	0.515 <i>0.374</i>				
Butterflies	0.870 <i>0.055</i>	0.159 <i>0.798</i>			
Moths	-0.035 <i>0.955</i>	-0.572 <i>0.313</i>	0.432 <i>0.467</i>		
Forbs	0.834 <i>0.079</i>	0.282 <i>0.645</i>	0.663 <i>0.223</i>	-0.014 <i>0.982</i>	
Woody plants	0.094 <i>0.880</i>	0.103 <i>0.869</i>	0.000 <i>1.000</i>	0.173 <i>0.781</i>	0.516 <i>0.374</i>

Table 3—Between-block correlations (Pearson) in functional group biodiversity measured by the Brillouin diversity index, with *P*-values in italics.

	<i>Breeding birds</i>	<i>Wintering birds</i>	<i>Butterflies</i>	<i>Moths</i>	<i>Forbs</i>
Wintering birds	0.257 <i>0.677</i>				
Butterflies	0.852 <i>0.067</i>	-0.213 <i>0.731</i>			
Moths	0.851 <i>0.067</i>	-0.108 <i>0.863</i>	0.801 <i>0.103</i>		
Forbs	0.854 <i>0.065</i>	-0.016 <i>0.980</i>	0.851 <i>0.067</i>	0.926 <i>0.024</i>	
Woody plants	0.525 <i>0.363</i>	-0.150 <i>0.810</i>	0.557 <i>0.330</i>	0.799 <i>0.105</i>	0.878 <i>0.050</i>

We calculated Pearson correlation coefficients to evaluate the degree of between-block similarity in biodiversity as measured by number of species (Table 2). In comparisons of fifteen pairs, no correlations were statistically significant, but significance was approached in correlations between Breeding birds and Butterflies, and Breeding birds and Forbs. A reliability analysis gave the intraclass correlation coefficient 0.5742 ($P = 0.0892$). We therefore found little evidence of agreement between biodiversity of blocks as measured by number of species: choice of functional group greatly influenced the outcome of biodiversity estimation. We used the same test to evaluate interblock comparisons of biodiversity as measured by the Brillouin diversity index (Table 3). Testing at the 5% level of significance, we found that the P -values indicated significant correlation between Moths and Forbs and between Woody plants and Forbs. Breeding birds and Butterflies, Breeding birds and Forbs, Butterflies and Forbs, and Breeding birds and Moths showed levels of correlation approaching significance. A reliability analysis provided an intraclass correlation of 0.8587 ($P = 0.0010$). There was clearly a greater level of interblock similarity in biodiversity as measured by the diversity index: in this case, choice of functional group did not always influence the outcome of biodiversity estimation.

For Breeding birds and Wintering birds, we found significant correlations between biodiversity measures based on number of species and the diversity index: that is, the measures indicated similar ranking of blocks (Table 4). For other functional groups, we found no significant correlations: that is, the ranking of blocks was determined by the choice of indicators.

Table 4—Correlation (Pearson) between diversity measured by (a) number of species and (b) diversity index for each functional group, all blocks aggregated, P -values in brackets.

<i>Functional group</i>	<i>Correlation between biodiversity measures</i>
Breeding birds	+0.901 (0.037)
Wintering birds	+0.884 (0.047)
Butterflies	+0.762 (0.134)
Moths	+0.627 (0.258)
Forbs	+0.735 (0.157)
Woody plants	−0.493 (0.399)

DISCUSSION

The first question posed was 'Does the choice of indicator functional group affect estimation of biodiversity?' When we quantified biodiversity of blocks by number of species, we found no between-group correlation. When we quantified biodiversity using the diversity index, we found some evidence of between-group correlation, but in a minority of cases. When results from all blocks were aggregated, we found no significant correlations between ranking of blocks by number of species and ranking of blocks based on the diversity index, with the exception of Breeding birds and Wintering birds. In conclusion, choice of functional group clearly affected biodiversity ranking of blocks.

The second question posed was 'Does the choice of quantification method affect the evaluation of biodiversity?' For Breeding birds and Wintering birds, choice of quantification method did not significantly affect the biodiversity ranking of blocks, but it did for all other functional groups.

With the exception of Wintering birds and Woody plants, all other functional groups and both quantification methods identified G1 as the most diverse block (though jointly with Block T1 in the case of Breeding birds). Results suggest that biodiversity scores based on indicator functional groups should be treated with great caution. They hint at the possibility of identifying reliable indicator functional groups and biodiversity measures, but much additional research is required. Functional groups selected for this study differed greatly in form and ecology, resulting in differences in survey and abundance quantification methods employed. For some groups (e.g. Forbs), we surveyed individuals in field boundaries only, but for others (e.g. Wintering birds and Butterflies), we included individuals in fields also. Blocks were intensively managed for agriculture, and management practice (which differed among blocks) may not have had similar effects on all functional groups. The effects of these factors on interblock and intergroup comparisons are unknown.

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