Drosophila diversity over a disturbance gradient

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Applied biodiversity research is often constrained by the time available to conduct proper research. An appropriate indicator taxon could simplify this kind of research. One of the prerequisites is that the diversity of the indicator shows a clear relation with the disturbance gradient. In this study, we investigate if *Drosophila* flies meet this prerequisite. Collections were made over a disturbance gradient from closed canopy forest to grassland in the Philippines. The results indicate that there are no differences in biodiversity among habitats regardless of the index used. However, the overlap between faunas of the two most extreme land use types is only 10% and most of the 35 species found clearly show habitat specialisation. In conclusion, the *Drosophila* communities show a clear response to the disturbance gradient but this phenomenon is not easily measurable with diversity indices.

Keywords: *Drosophila*, biodiversity, community composition

Applied biodiversity research for environmental studies in third world countries are often constrained by the limited time span available before a report has to be finished. And if there are already data available for an area, it is often limited to the more undisturbed areas. This lack of time and data often results in generalisations based on general ideas, rather than on the real situation. This problem could be relaxed if one group could serve as an indicator group for the specific aspect, in this case biodiversity. Such an indicator species or group should be representative of the diversity of other groups and show a clear relation with the disturbance gradient. In this study we investigate if the diversity in *Drosophila* flies has a clear relation with the disturbance gradient.

Davis & Jones (1993) used the species of the genus *Drosophila* as an indicator of habitat type and habitat disturbance in tropical forest on Borneo. *Drosophila*'s are a useful indicator group for biodiversity because they normally have a lifespan of less then a month so that they respond quickly to changes and historical effects are minimised. Their mobility is also an advantage because the absence of a species is caused by the unsuitability of the habitat and not a failure to colonise. Furthermore, *Drosophila*'s are numerous and easily collected using oviposition traps or rearings from fallen fruits so that the collection of sufficient number of individuals is possible.

Magurran (1988) defines biodiversity as: '... the variety and abundances of species in different habitats.' Biodiversity is often translated with just the number of species. However, the distribution of the individuals among the species is also of importance. If all but a few individuals belong to one species, the diversity is lower than when all the individuals are equally distributed among the species. Not all variation between communities is addressed using diversity indices. Similarity indices (see Wolda 1981) are used to examine the similarity between communities.

The aim of this study is to investigate if the *Drosophila* communities in the different habitats show a clear relation between diversity and the degree of disturbance. The hypothesis is that the more disturbed the habitat, the lower the *Drosophila* diversity. The land use types under investigation vary between primary forest and grassland. All the other land use types can be ranked between them. This sequence is used to calculate the correlations with the indices and the overlap percentages.

MATERIAL AND METHODS

We collected frugivorous *Drosophila* in the Philippines, in 1992. The number of recorded *Drosophila* species for the Philippines is around 80 species (Delfinado & Hardy 1971; Okada 1981; Baltazar 1991, M. Toda, Hokkaido University, personal communication). The collection sites were located on the slopes of the Sierra-Madre mountain range. This mountain range, in the

Northeast of Luzon, is bounded by the east by the Pacific Ocean and in the west by the Cagayan Valley. The Sierra-Madre has one of the last remaining larger areas of tropical rainforest in the Philippines, the biggest piece of the mere five percent of tropical rainforest that remains in the Philippines (Danielsen *et al.* 1993). By now, the Central Valley area is either grassland or agricultural fields and plantations containing rice and other commercial crops. Towards the mountains, it changes first to kaïngins (intensive slash and burn agriculture), then to secondary forest and finally to primary forest.

The collections were made in ten different habitats, which ranged from grassland to secondary forest. The difference in floral composition between the habitats was great enough to expect effective differences between the habitats. The disturbance ranking is made using aspects like canopy cover, vegetation structure, stage in the degradation and recovery sequence and location in relation to other habitats.

1.	Closed	Primary forest has a closed canopy and human influence is limited. Some gathering of Non Timber Forest Products (NTFP) by Agta's. The site was logged over a long time ago, but the canopy has closed again.
2.	Open	The biggest trees are logged and removed. Sometimes, seedlings of various softwood species are planted.
3.	Patch	Patches of logged over forest that remains between other habitat types like in this case *semi*-permanent agricultural fields.
4.	Scrub	Same as *Open*, but all the trees of some size are removed. Remains mostly as a patchy distribution within the grasslands.
5.	Pioneer	Pioneer vegetation on recovering kaïngins. The kaïngins are left and all kind of pioneer softwood species are currently recolonising the lands.
6.	Kaïngin	Logged over forest or scrub land that is converted into agricultural fields. The land is cleared by cutting all the vegetation and burning the remains. This will give a harvest for a few years. Thereafter, a new piece of land must be cleared.
7.	Semi	If clearing a new piece of land is no longer possible, kaïngins tend to be used for a much longer period and get a semi-permanent character.
8.	Ban	When the land is denuded after a few years, bananas can still grow there and are frequently planted of old kaïngins and semi permanent agricultural fields.
9.	Ref	Grasslands are reforested with (mostly) softwood species in order to diminish the deforestation.
10.	Grass	The final stage in the process. Sometimes used for cattle.

Sites 1, 2, 4, 5, 6, 9 and 10 are located east of Bintacan, a barangay of the municipality of Ilagan, Province Isabela. Site eight is located near town proper of San Mariano, Isabela. The last two sites, 3 and 7 are in Kajappa, barangay Baliwag, in the municipality of Peñablanca, Cagayan.

We used oviposition traps baited with banana to standardise the sampling and to avoid difficulties with the comparison of habitats. Many natural breeding substrates are used for breeding by a limited number of species. Bananas have proven to be a quite general not-selective breeding substrate for frugivorous *Drosophila* species.

Two series of collections were made but not all habitats could be covered in both series. Four habitats were sampled in both series, the rest only in one of the two series. Two traps were placed in each of the different habitats under investigation that week, with at least 200-m distance between the two traps. The traps were constructed from 500-ml transparent margarine containers hanging on a nylon line of about one meter long. A hole of Ø 2.5-cm, covered with 1.5-mm mesh, was positioned on one side of the trap. The hole faced slightly downwards to prevent rain from coming in. The mesh allowed *Drosophila* access to the bait inside, but prevented larger animals from entering. A small banana, known on the market as the 'Manila', was used as bait.

The traps were exposed in the field for seven days. After that period, the adults were sampled at the collection site and preserved in alcohol (70%). The baits were brought to the laboratory and the flies were reared out. Newly emerged flies were collected once a day and preserved. Two series were counted both consisting out of adults from the field and offspring reared from the bananas. Insects of the various samples were identified and sexed. Species of the genus *Zaprionus*

Table 1. Indices used in this research. After Magurran (1988).

ES	Rarefraction
DMG	Margalef's diversity index
DMN	Menhinick's index
H	Shannon diversity index for species richness
HE	Shannon diversity index for evenness
HB	Brillouin index for species richness
HBE	Brillouin index for evenness
RECD	Simpson's index
McU	McIntosh's index of species diversity
McD	McIntosh's index of dominance
McE	McIntosh's index of evenness
d	Berger-Parker diversity index
alpha	The alpha (α) of the log series model

are closely related to the genus *Drosophila* and also included in the research. The systematics of the Filipino *Drosophila*'s is quite complicated (most species belong to the *melanogaster* species group), but most individuals can be assigned to the correct species. Females of the four *bipectinata* subgroup species are indistinguishable and therefore assigned to the species proportionally to the counts of males. Individuals were assigned to the category indeterminate if positive identification was impossible.

Magurran (1988) lists 13 biodiversity indices (Table 1), and not one of them seems to be a better choice beforehand, so we decided to calculate all these indices for all samples. Calculating all indices also gives us insight in the robustness of the results. All the indices (Table 1) are calculated for all the counted samples. We used the Kendall Rank Correlation test to calculate the correlations between the indices and the disturbance ranking. A lot of different similarity indices are developed (Wolda 1981). In this study I will use the percentage similarity of Renkonen (1938), because this is the most straightforward index. The relation between the difference in disturbance ranking and the overlap percentages was tested using regression analysis.

RESULTS

The time between the collections of the two series counted is 12 weeks. This gives the total of four groups that were analysed; first and second adults series, and first and second offspring series. All the indices are calculated for all the samples. The correlations between the different indices and the original disturbance ranking are presented in Table 2. None of the indices has, in all four series, a significant correlation with the disturbance ranking. This indicates that there is no change in number of species, or in the relative distribution in abundances.

Magurran (1988) divides the indices in two groups: Species richness indices and evenness indices. These are two independent characteristics of biodiversity and none of the indices is a good indicator for both aspects. She found (strong) correlations within these groups, and no correlations between indices of these groups. The general picture holds for my data, although the differences are not that clear. Significant ($p<0.05$) correlations are found for all the combinations within the evenness group, and for 62% of the combinations within the species richness group of indices. The percentage significant correlations between indices of both groups is 42%. The best aspect specific indices within a group, species richness or evenness, should have a good correlation with the other indices within the same group and no or a limited number of good correlations with the indices of the other group. Based on this, the best species richness index is the number of species (S) and the best evenness index is the Berger-Parker index ($1/d = N/N_{max}$).

Adult samples have more species ($p<0.001$ Wilcoxon matched pairs signed rank test (WMPSR)) and generally higher values for most indices ($p<0.001$ (WMPSR) except Berger-Parker and MacIntosh species richness). Offspring samples have more individuals ($p<0.001$ (WMPSR)) and higher values in two of the 13 indices ($p<0.001$ (WMPSR) for Berger-Parker and MacIntosh species richness).

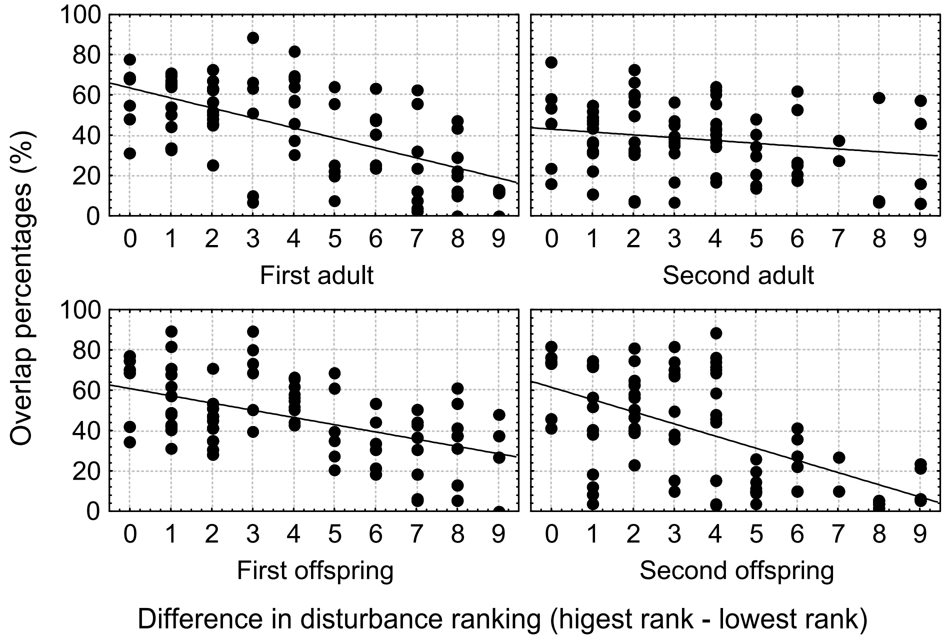

Figure 1. Difference in disturbance ranking versus overlap percentages.

Table 2. Correlations between the biodiversity indices and disturbance ranking.

	S	N	alpha	H	HB	DMG	McU	I/D	d	McD	HE	EHB	McE	ES	DMN
First Adult															*
Second Adult															
First Offspring	**			*	*	*								*	
Second Offspring			*			*									*

N: Number of individuals; S: Number of species. See Table 1 for the other abbreviations. *: 0.01<P<0.05, **: 0.001<p<0.01

The overlap percentages between samples vary between 15.9% and 78.0% (average 52.0%) for the adult samples and between 34.2% and 81.8% (average 63.5%) for the offspring samples. It is predicted that the overlap percentages are lower between samples of different habitats, than within the same habitat. This is true for three of the four series, except the second adult series (Mann-Whitnney U-test, one tail probability adult1: p=0.042; adult2: p=0.184; offspring1: p=0.034; offspring2: p=0.005). It is also predicted that the overlap percentages will be smaller if the difference between disturbance rankings is larger because the differences between the habitats are larger (Fig. 1). The correlations between the difference in disturbance ranking and the overlap percentages are significant for all series, except the second adult series (adult1: r^2=0.355, p=0.000; adult2: r^2=0.039, p=0.084; offspring1: r^2=0.000, p=0.000; offspring2: r^2=0.000, p=0.000). The data used for the calculation of the correlations is not fully independent, because every single sample is used several times to calculate the different overlap percentages with the various other samples. This could result in an overestimation of the correlation if one of the samples has a larger than proportional influence. A jack-knife procedure showed that none of the samples has such an disproportional influence, and confirms the general pattern as found.

DISCUSSION

None of the diversity indices shows a clear correlation with the disturbance ranking in all the four series. This could lead to the conclusion that land use does not affect *Drosophila* diversity. However, this is not supported by the overlap percentages, which indicate that there are large differences between habitats in species composition. The overlap percentages between samples of the same habitats are generally larger than between samples of the same habitat. This is a second indication that there is a consistent influence of land use or disturbance on the *Drosophila* fauna(s). Not only are there differences, but these differences are larger as the difference in disturbance ranking is larger (Fig. 1). From this, the conclusion follows that disturbance has a large impact on the *Drosophila* fauna.

The disturbance ranking of land use types was made based on human activities and natural recovery processes. Almost implicit in this disturbance ranking is the idea that there was only forest before human activity changed the landscape. However, there are natural habitats that look like human-made habitats like natural grassland areas and it would be strange if there were no species specialised on such natural habitats. Examples can be found in the birds, more specific in the Estrildid Finches (Family Estrildidae). Some of them are endemic for the Philippines and restricted to grasslands (Gonzales 1988) and are culture followers (Rabor 1977). Seventeen of the 28 *Drosophila* and *Zaprionus* species show a clear significant preference (Kolmogorov-Smirnov 1-sample test (species number versus total number of individuals per disturbance rank)) for undisturbed (6), disturbed (7) or intermediate (4) areas. The other species do not have any clear preference for a certain habitat category.

The disturbance ranking is made intuitively using aspects like canopy cover, vegetation structure, stage in the degradation and recovery sequence and location in relation to other habitats. The question remains if that disturbance ranking is the best ranking possible. One way to get some insight in this is to make all possible rankings and see which of those rankings has the best fit with the data. This ad-hoc analysis is in principle circular, especially if we would have used this to change the a priori established ranking, but gives anyway insight in the robustness of the analysis. Changing the disturbance ranking only gave worse results. The correlations between the disturbance ranking and the biodiversity indices did not yield more significant results for any of the indices. A similar picture arose from changing the disturbance ranking and calculating the correlations with the overlap percentages. Here also, the a priori made disturbance ranking gave the strongest results.

The usefulness of *Drosophila*'s as a biodiversity indicator is, based on the results in this study, still unclear. The aim of this study was to investigate if the *Drosophila* diversity has a clear relation with the disturbance gradient. The answer is clearly positive when we look at overlap percentages, but it is not easy to detect that with biodiversity indices. Another question, one that was not within the scope of this study and will not be answered is, is the *Drosophila* species group representative for the biodiversity as a whole?

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