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The Scarabaeinae (Insecta: Coleoptera) an Animal Group for Analysing, Inventorying and Monitoring Biodiversity in Tropical Rainforest and Modified Landscapes

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Introduction

The loss of species as a consequence of the increasing alteration of ecosystems by human activities has promoted, in the last decade, the search for conceptual frameworks to explain the origin and function of biological diversity, and to propose feasible programs of conservation. (In the current, abundant literature see Wilson, 1988; Solbrig, 1991). One of the ecosystems which is under the greatest threat as a result of anthropogenic activities is that made up of distinct types of tropical forests: from the rain forests to the high and low deciduous forests. Of all terrestrial ecosystems, tropical forests have the greatest species diversity (a diversity), the most complex ecological structure and great spatial heterogeneity (ß diversity). Taking into account the difficulties in evaluating the diversity of organisms and the complexity of ecosystems, one strategy which might prove fruitful is that which involves directing the research toward monitoring and gaining information about indicator groups of organisms. However, adequate guidelines for doing so are scant or completely lacking, as are fieldwork guidelines for the selection of indicator groups in distinct types of ecosystems (see Kremen, 1992).

Mammals, birds, flowering plants and butterflies (Brown, 1991; Kremen, 1992) have been used as indicators for the analysis of biodiversity. Recently, studies for the use of other insects in this type of research have been conducted (Halffter *et al.*, 1992). The dung beetles of the subfamily Scarabaeinae (Coleoptera: Scarabaeidae) are a group of insects which are well represented in the tropical region. The number of species ranges between 25 and 70 in tropical rain forests (see Halffter, 1991) and is as high as 124 species in African savanna (Cambefort, 1985, 1986). It has been demonstrated in the last few years that the Scarabaeinae are very sensitive to the destruction of tropical forest (Howden and Nealis, 1975; Klein, 1989; Halffter *et al.*, 1992). The objective of this paper is to give the theoretical and practical elements for proposing the Scarabaeinae guild as a parameter group for studying the basic aspects of biodiversity in tropical forests and for evaluating and monitoring the effects of anthropogenic landscape alteration.

Scarabaeinae as a parameter for biodiversity studies

There is a clear consensus that we are not able to evaluate the total biodiversity of tropical forests, nor can we measure the effects of environmental alteration on each one of the species (di Castri and Younès, 1990; Solbrig, 1991; Coddington *et al.*, 1991).

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One of the requirements for the evaluation of biodiversity which is most difficult to meet (whether at the α, ß or γ level) is finding one or various groups of organisms which allow for the establishment of reliable relationships between the information which is obtained in the field and species richness and other measures related with the diversity of the ecosystem. This requires finding one or more parameters that through their quantitative expression (which is therefore comparable) allow us to approximate what happens in the whole ecosystem. A good parameter of biodiversity should possess various characteristics (see related guidelines in Coddington *et al.*, 1991; Kremen, 1992):

1) Said parameter should be based on a group of organisms which represent a rich and well defined guild in the type of ecosystem which one wishes to interpret. This guild should be important in the structure and functioning of the whole ecosystem.

2) The guild selected should reflect any change which the communities undergoes, for example, reduction in surface area or various types of disturbance. The group should "be capable of providing a continuous assessment over a wide range of stress" (Noss, 1990).

3) The organisms which make up the guild have to be easy to catch and standardizable so that the pre-established methodology can be applied in any location following a standard program. This will make possible the comparison of results obtained in different geographic locations of the same ecosystem, in areas of different sizes or degrees of disturbance or under different biogeographic conditions. The value of the parameter lies in the possibility of making comparisons and, as such, evaluations and predictions.

4) The capture data should provide sufficient ecological information for the determination of the composition and structure of the guild and its interactions with the rest of the community. This ecological information is what will make the jump from the parameter group to the whole community possible.

5) The taxonomy of the group must be well established, to the point where there is no major confusion regarding the separation of species. For our purposes a group is useless if the quantitative results are affected by identification errors. If we want to extend our comparison in a geographic sense to include communities which inhabit the same kind of ecosystem, but do not necessarily include the same species, the necessity of well established taxonomy is even more important.

6) The group must possess certain characteristics so that collecting individuals and other activities necessary to the study will not put the conservation of that group in danger.

7) The parameter group must not only provide information about the intact community, but must also serve as a measure of the reduction in biodiversity brought about by distinct causes: reduction of the area by geographic causes or by human activity, distinct degrees of disturbance, management or other anthropogenic activities.

As a result of our published research (Halffter, 1991; Halffter *et al.*, 1992) as well as that which we are currently pursuing, we are able to propose the Scarabaeinae guild as a parameter group which is particularly appropriate for use in tropical rain forest, which is perhaps the most difficult type of ecosystem to analyse (see Kremen, 1992, regarding the use of butterflies as bioindicators in this type of ecosystem). It is very likely that the Scarabaeinae would also be useful as indicators in savannas and other open tropical formations, but there are no studies of this.

We have based the selection of the Scarabaeinae as one of the parameters of biodiversity in tropical forests on the following reasons:

1) The Scarabaeinae beetles form a well defined guild, in both functional and taxonomic senses (being clearly monophyletic). Their predominant participation in the recycling of excrement (as well as cadavers and decomposing fruit in the American tropical forests and forests of southeastern Asia) make them very important elements of the whole ecosystem (See Halffter and Edmonds, 1982; Hanski, 1989; Hanski and Cambefort, 1991; Halffter, 1991).

In the American tropical forests and those of southeastern Asia many species have compensated for the historical reduction in the number of large mammals (taken in the evolutionary and biogeographic sense) which produce dung by adopting necro-coprophagous feeding habits. These feeding derivations can manifest as saprophagy (consumption of decomposing fruit) and even strict necrophagy (see Halffter and Matthews, 1966; Hanski, 1989; Hanski and Cambefort, 1991; Halffter, 1991).

2) In the same geographic area the taxonomic composition of the guild within the tropical forest is completely distinct from that which is found in locations where the forest has been cut. The internal structure and organization are also different. As a result, in each of the distinct locations studied we can speak of the guilds as those found within the forest and those of locations which have been cut. A transition guild is found in the ecotones, and this has its own ecological structure. In this case we are referring to landscapes where the tropical forest has been (or continues to be) the dominant type of community. Under these conditions in the deforested areas the Scarabaeinae guild is less rich than it is in the forests.

The existence of a series of notable differences between the guild of the forest and that of deforested areas makes the Scarabaeinae an excellent instrument for measuring the consequences of the change or partial transformation of regional forest ecosystems to biodiversity (Halffter *et al.*, 1992). As such this is a group which clearly reflects anthropogenic changes: fragmentation, defaunation, ecosystem simplification, effects of the introduction of cattle, etc.

3) In general terms the biology, behaviour, ecology, taxonomy and phylogeny of the group have been thoroughly studied (see overview papers by Halffter and Matthews, 1966; Halffter and Edmonds, 1982; Hanski and Cambefort, 1991). This knowledge, which has been recorded in a significant number of taxonomic monographs as well as local and regional faunistic papers, makes it possible for non-specialists, making a reasonable effort, to work with this group.

4) The method of capture has been standardized for quantitative sampling. It is simple: pit-fall traps are baited with carrion, dung or decomposing fruit. The same capture methods should be used in different locations so that the results are comparable (Figure 1).

The simplicity and low cost of the sampling procedure, as well as the universal and comparable nature of the data make the Scarabaeinae an ideal group for comparative studies between different geographic locations of the same type of ecosystem. The necessity for and the importance of these studies has been pointed out by di Castri and Younès (1990). For these same reasons, as for the ecological reasons cited in point 2, Scarabaeinae beetles represent an exceptional group for the comparison of landscapes with different degrees of anthropogenic disturbance, where tropical forest originally dominated.

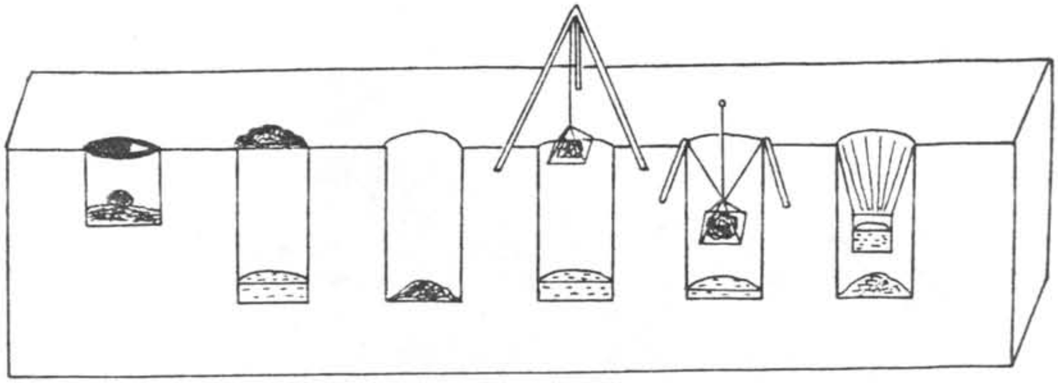


Figure 1. Types of traps commonly used for collecting coprophagous or necrophagous beetles (modified from Lobo *et al.*, 1988)

The bait for coprophages is usually human excrement or the excrement of some herbivore such as cows, mules or horses. The bait most commonly used to catch necrophages is a piece of fish (20g). All traps are buried in the soil and a plastic cover may be used so that rain doesn't enter the trap and so that the sun doesn't desiccate the bait too rapidly. These traps are inexpensive and can be bought in any country. We propose the use of trap A, which is a box with a triangular opening in the cover so the volatile compounds of the bait can escape and so the beetles can fall into the trap. The traps are set at sunrise and are checked and rebaited at sunset in order to catch diurnal and nocturnal species. We feel that putting soil in the traps, instead of a killing compound allows for the return of the insects to the forest once they have been identified, thus avoiding any possible effect on the population in zones which are heavily affected. Only when there is a doubt about identification might a captured individual be sacrificed for more detailed taxonomic analysis.

The simple sampling methods (since they require neither specialized equipment nor personnel) make it possible to establish continuous and long term monitoring programs. With adequate field information it is possible to make predictions about what might happen to the diversity and structure under different degrees of fragmentation and disturbance in tropical forests. A useful approximation is the comparison of unmodified tropical forests with landscapes of distinct degrees of transformation when the work is carried out in an biogeographically coherent area, to avoid the "noise" that faunistic differences can introduce (see Halffter *et al.*, 1992). Another approximation can be made by comparing the results of captures made before disturbance occurs with those of captures made after disturbance. This comparison is made possible in various locations of tropical America by existing collections. In any case, a simple monitoring program can indicate the accuracy with which the predictions are met. This could be one of the elements for a global interpretation of what is happening to biodiversity.

5) There are a certain number of taxonomists who specialize in different groups of Scarabaeinae in different locations in the world. It would be relatively easy to make field keys and have regional reference collections for quick species identification and for monitoring guilds in different locations with tropical forest.

Levels of biodiversity which can be studied using Scarabaeinae

Of the different levels of organization at which biodiversity can be studied, Scarabaeinae offer the possibility of studying biodiversity at the genetic and population level in landscapes with tropical forests. As such, at the genetic level, the survival of some forest species in forest patches or in modified ecosystems offers an "archipelago" system in which areas, distances and time of separation can be accurately recorded. At the population level, the introduction of various species to the Americas, but in particular the introduction of *Digitonthophagus gazella* (Fabricius), provides an excellent model for the analysis of the effects on the native guild. This African species was released in Texas in 1972 by the Department of Agriculture of the United States of America (Blume and Aga, 1978; Fincher *et al.*, 1983). There is evidence that this species has caused changes in the guild in Texas (Howden and Scholtz, 1986). In Mexico this species has expanded throughout all tropical parts and some areas of the Altiplano. At the Instituto de Ecología (Xalapa, Mexico) we are studying the changes which the abundance of this species, including its dominance, could provoke in the guild in different forest landscapes or modified ecosystems.

In spite of the previously mentioned possibilities, it is the analysis of biodiversity at the community level where the Scarabaeinae beetles provide an advantageous parameter in tropical forest ecosystems and the ecosystems derived from them. For the analysis of this group as a parameter at this level, among the elements which must be measured are the following:

For the analysis of a diversity of the guild:

1. Species richness. Number of species in each community.

2. Diversity and equitability indices. We propose the use of indices based in the proportional abundance of species: Shanon, Simpson, Hill. The last set of indices (those of Hill) are perhaps the most convenient.

For the analysis of guild structure:

3. Analysis of species abundance by rank/abundance plots (number of individuals or biomass).

4. Trophic diversity: generalists, strict coprophages, strict necrophages and saprophages.

5. Temporal diversity in activity. Separating daily activity (diurnal, nocturnal and crepuscular species) and annual activity (changes in species composition and abundance over the course of a year).

6. Spatial segregation. Based on food source (rollers and non-rollers), and considering spatial species separation caused by external factors (*e.g.* microclimatic variations and spatial distribution of mammals).

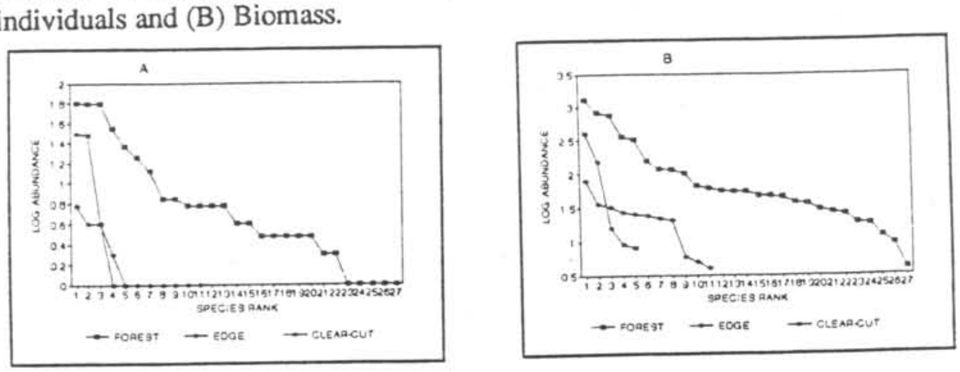
Of the previously mentioned elements, with only element 1 the researcher has base for the comparison of different locations of forest or modified ecosystems, if one has one or two well studied locations which facilitate the interpretation of the other data. Element 2 refines the interpretation of a diversity. Elements 3 to 6 are necessary to analyse the change in modified ecosystems, between different sites of the same ecosystem or between different biogeographic regions. This analysis allows for the evaluation of the effect of the modification of the tropical rain forest on the composition and structure of the guild of this group of insects (Box 1).

Box 1

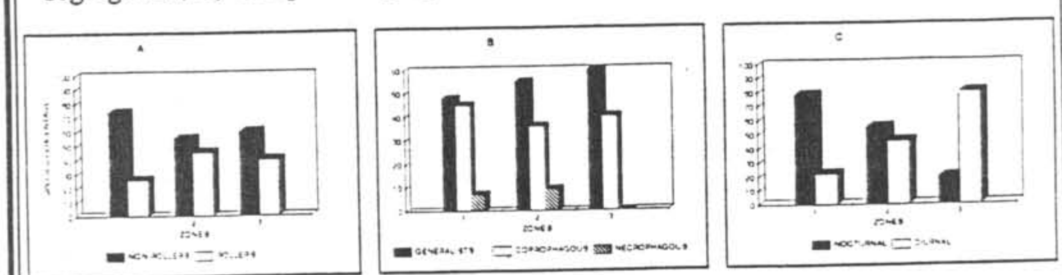
An example of diversity analysis in a guild of coprophagous and necrophagous Scarabaeinae beetles in the rain forest of Palenque, Mexico and an area which was cut in 1965 (data from Halffter *et al.*, 1992).

	Forest	Edge	Clear-cut
Richness	27	11	5
Diversity	2.5	2.12	1.01
Equitability	0.76	0.88	0.62

Dominance-diversity curves for three zones at Palenque: A) Number of individuals and (B) Biomass.



Ecological niche segregation in the Scarabaeinae guild in three zones at Palenque: 1) Forest, 2) Forest edge, 3) Clear-cut. A) Food relocations method, B) Feeding segregation, C) Temporal segregation.



Richness, diversity and equitability values decrease from the forest to the clear-cut. Distribution of abundance in the forest is more equitable than at the edge or at the clear-cut. In the three zones non-roller beetles dominate rollers and generalists dominate coprophages and necrophages. Nocturnal beetles dominate diurnal beetles in the forest and at the edge, but in the clear-cut this relationship is reversed and the diurnal beetles dominate.

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Wilson, E.O. (ed.) (1988) *Biodiversity.* National Academy of Sciences Press, Washington, D.C. 521 pp.Box 1