IBOY 2000 (International Biodiversity Observation Year)

LA MACROFAUNE DU SOL : UNE RESSOURCE EN DANGER DANS UN MONDE EN CHANGEMENT

RAPPORT DU COLLOQUE INTERNATIONAL

19 au 23 Juin 2000 - Bondy (France)

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RESUME DU PROJET

Le prochain grand défi pour le développement de l'agriculture est de conserver la biodiversité et développer l'usage des ressources biologiques complètement négligées pendant les décennies de la révolution verte. Les invertébrés du sol sont des acteurs irremplaçables de la formation du sol et de la conservation des écosystèmes naturels; et la non-durabilité générale actuelle des systèmes agricoles mondiaux provient, au moins partiellement, de leur disparition. D'une manière générale, les systèmes de l'agriculture intensive diminuent fortement la diversité et l'abondance de la macrofaune du sol; des colonisateurs exotiques agressifs peuvent occasionnellement se substituer aux communautés d'origine et dégrader les sols et la végétation. C'est le cas, par exemple : des fourmis champignonistes coupeuses de feuilles dans les Iles Caraïbes et l'Amérique tropicale, des vers de terre compactants dans les pâturages amazoniens ou des fourmis envahissantes dans les champs de riz d'Argentine.

Les pollutions chimiques dûes aux activités humaines altèrent aussi la composition des peuplements d'invertébrés des sols qui peuvent être utilisées comme indicateurs des pollutions diffuses (par exemple les métaux lourds et les résidus de pesticides) comme bioaccumulateurs.

Les sols peuvent héberger des peuplements d'invertébrés abondants et divers. qui sont des indicateurs très sensibles de la qualité des sols et de leur fertilité. Les organismes ingénieurs occupent une place particulière dans cette grande diversité d'espèces, de tailles et de stratégies adaptatives. Ces invertébrés de grande taille, capables de creuser et de transporter le sol, déterminent l'activité d'organismes plus petits, par leur activité mécanique et la redistribution des ressources nutritives qu'ils opèrent.

Les ingénieurs du sol, produisent des structures organo-minérales (nids, galleries, turricules....) qui peuvent persister pendant des périodes allant de quelque jours à plusieurs mois, voire des années. Ce sont les vers de terre, les termites, les fourmis et un certain nombre d'invertébrés d'une taille égale ou supérieure à un centimètre.

La gestion de ces peuplements est maintenant considérée comme l'un des moyens d'améliorer la durabilité des systèmes agricoles. La mise au point de techniques utilisant cette ressource, nécessite une connaissance approfondie de la composition de leurs peuplements, et de leur réponse à des conditions spécifiques du sol et aux perturbations.

L'acquisition de cette connaissance est l'objectif de ce projet, inclus dans le programme international IBOY (International Biodiversity Observation Year)/ DIVERSITAS. Des données ont déjà été collectées sur les peuplements de macroinvertébrés dans plus de 500 sites différents avec la méthode standard TSBF (Anderson et Ingrain, 1989[1]). Après une réflexion sur la méthode et le mode d'exploitation des récoltes, ces données seront organisées dans la base de données MACROFAUNA et traitées pour produire des indices synthétiques de la qualité du sol et améliorer la connaissance de cette ressource à l'échelle mondiale.

Un site sera créé sur le réseau Internet comprenant une description détaillée des méthodes , des illustrations, des clés d'identification, des formats de saisie de l'information et un accès à la base de données. Les informations sur les technologies disponibles, et en développement, basées sur les activités de la macrofaune seront aussi fournies.

[1] Anderson JM, Ingram JSI (1993) Tropical Soil Biology and Fertility. A handbook of methods. 2nd edition. CAB International

IBOY 2000 (International Biodiversity Observation Year)

LA MACROFAUNA DEL SUELO : UN RECURSO EN PELIGRO DENTRO DE UN MUNDO EN CAMBIO

PEPORTE DEL COLOQUIO INTERNATIONAL
19-23/06/2000 - Bondy (France)

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RESUMEN DEL PROYECTO

Conservar la biodiversidad y potenciar la utilización de los recursos biológicos constituye el próximo gran reto para el desarrollo de la agricultura; en efecto, estos dos objetivos han sido completamente descuidados durante los decenios de la revolución verde. Los invertebrados del suelo son incontestablemente los actores ireemplazables de la formación del suelo y de la conservación de los ecosistemas naturales; la insostenibilidad general de los sistemas agrícolas mundiales existente en la actualidad proviene, al menos en parte, de la desaparición de los invertebrados del suelo. De manera general, los sistemas de agricultura intensiva agotan severamente la diversidad y la abundancia de la macrofauna del suelo; así, colonizadores exóticos agresivos pueden sustituir ocasionalmente las comunidades de origen y degradar el suelo y la vegetación. Citaremos por ejemplo: las hormigas (cultivadoras de hongos) cortadoras de hojas en el Caribe, las lombrices de tierra compactantes en los pastizales amazónicos o las hormigas invasoras en los campos de arroz de Argentina.

Además, la contaminación química ocasionada por las actividades humanas alteran también la fauna del suelo; la composición de las comunidades de la fauna del suelo puede ser así utilizada como indicador de la contaminación difusa (por ejemplo los metales pesados y los residuos de pesticidas), indicador *sensu stricto* o o por bioacumulación.

Los suelos pueden alojar comunidades abundantes de invertebrados fuertemente divesificadas. Son indicadores muy sensibles de la calidad del suelo y de su fertilidad. Dentro de esta gran diversidad de especies, tamaños y estrategias adaptativas diferentes, se distinguen los organismos ingenieros. Estos invertebrados de gran tamaño capaces de cavar y de transportar el suelo, determinan la actividad de otros organismos mas pequeños, por su acción mecánica y la redistribución de recursos nutritivos que realizan.

En efecto, el grupo de los ingenieros del suelo, reúne todos los invertebrados que producen estructuras organo-minerales (nidos, galerías, turrículos...) que pueden existir durante periodos de tiempo que van desde algunos dias a algunos meses, e incluso años. Se trata de las lombrices de tierra, las termitas, las hormigas y un cierto número de invertebrados de un tamaño igual o superior a un centímetro.

La gestión de estas poblaciones es ahora considerada como un medio para mejorar la durabilidad de los sistemas agrícolas. Es por lo que la puesta a punto de técnicas que utilizan este recurso, necesita un amplio conocimiento de la composición de esas poblaciones, de su reacción frente a las condiciones específicas del suelo y de sus perturbaciones.

Todo esto constituye nuestro proyecto incluido en el programa IBOY/DIVERSITAS, que debe reagrupar todos los datos existentes sobre las poblaciones de macroinvertebrados recolectados en mas de 100 sitios con el método estándar « TSBF » (Anderson y Ingram, 1993[1]) igualmente debe estimular la recolección de nuevos datos, organizarlos en la base de datos MACROFAUNA y tratarlos para crear índices sintéticos de la calidad del suelo y mejorar el conocimiento de este recurso a nivel mundial.

Se creará un sitio Internet incluyendo una descripción detallada de los métodos, con ilustraciones, claves de determinación y bases de datos. Las informaciones sobre las tecnologías disponibles, y en desarrollo, basadas sobre las actividades de la macrofauna serán también proporcionadas.

[1] Anderson JM, Ingram JSI (1993) Tropical Soil Biology and Fertility. A handbook of methods. 2nd edition. CAB International

I.B.O.Y. 2000 (International Biodiversity Observation Year)

SOIL MACROFAUNA : AN ENDANGERED RESOURCE

IN A CHANGING WORLD

REPORT OF AN INTERNATIONAL WORKSHOP
held at Bondy (France) 19-23 June 2000

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Summary of the project

The next great challenge for agriculture development is to save the biodiversity and develop use of biological resources that have been totally neglected during the decades of the green agricultural revolution. Soil invertebrates are indeed irreplaceable actors of soil formation and conservation in natural ecosystems and the general unsustainability of agricultural systems

worldwide is attributable, at least partly, to their local disappearance. Intensive agricultural systems generally deplete severely their diversity and abundance, and aggressive peregrine colonisers (e.g., leaf cutting ants in Carribean islands and tropical America, « compacting » earthworms in Amazonian pastures or invasive ants in abandoned paddy rice fields in Argentina) may occasionnally substitute native communities and degrade soils or vegetation.

Chemical pollutions due to human activities also adversely affect soil fauna; in this case, the composition of faunal communities may be an accurate indicator of diffuse pollutions (e.g., heavy metals and pesticide residues), as indicators sensu stricto, or bioaccumulators.

Soils of the world host abundant and highly diverse invertebrate communities. They are sensitive indicators of soil quality and recognised agents of their fertility. Among the vast diversity of species, adaptive strategies and size range represented, a specific group, also called soil ecosystem engineers, includes large invertebrates that actually determine activities of other smaller organisms through the mechanical activities that they realise in soil.

Soil engineers include all the invertebrates that produce organo-mineral structures (nests, galleries, casts...) that may persist from days to months and years : earthworms, termites, ants and a number of other invertebrates of a size larger than ca. 1cm.

Management of their communities is now considered an efficient way to improve the sustainability of agricultural systems. The design of techniques that make use of this resource will require a comprehensive knowledge of the composition of these communities worldwide, and their reaction to a large set of specifific soil conditions and disturbances.

This proposal, promoted by DIVERSITAS/IBOY (International Biodiversity Observation Year), will collect all the existing data on macro-invertebrate communities sampled in over 500 sites with the TSBF standard method (Anderson JM, Ingram JSI, 1993[1]). A handbook of methods. 2nd edition. CAB International, stimulate further data collections, organise them in the MACROFAUNA database and process these data to produce comprehensive indexes of soil quality and improved knowledge of this resource worldwide.

[1] Anderson JM, Ingram JSI (1993) Tropical Soil Biology and Fertility. A handbook of methods. 2nd edition. CAB International

A site will be created on the WWW with a description of methods, illustrations, identification keys and databases. Information on available and developping technologies aiming at stimulating faunal activities will also be provided.

Objectives of the project:

- To provide standard tools for the quantitative study of communities;
- To collect existing data in a database and evaluate the state of Macrofauna on a worldwide basis;
- To organise information and communication during the International Biodiversity Observation Year in 2001-2002

Objectives of the workshop:

The workshop gathered 40 participants from 12 different countries to evaluate the current state of methodology used to assess macroinvertebrate communities, organise and review the existing datasets and prepare a strategy for diffusion of data and knowledge worldwide.

The first day of the workshop was devoted to an introductory lecture on the theme and a presentation of the IBOY programme and the Macrofauna project. Six presentations of datasets from Peru, Brazil, India, Mexico, Ivory Coast and France were presented (Table 1). During the next four days, participants split into five groups to review the current state of issues of high relevance at that stage of the project:

1. Methods
2. Taxonomy
3. Database
4. Treatment of data
5. Communication-Information

Group 1 : Field and laboratory Methodology

Group members :

David.E. Bignell (Chair)
Eric Blanchard (Reporter)
Eleusa Barros
Elizabeth Fernandez -Correia
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Juan.Jose Jimenez
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Bikram Senapati
Stéphanie Topoliantz

1. Definitions of site-related terminology used in this project:

REGION – geographical, geopolitical or biogeographical demarcation (large).

LOCALITY – a site (generally a larger site) or a series of adjacent sites.

ZONE – A plot or a series of plots with a characteristic original vegetation, soil and climate. A zone can be characterized by several land uses. A zone can be sampled via a plot or several plots, and at different times or seasons.

PLOT – a piece of land where a transect is placed.

LANDUSE – the current management in a plot.

2. Sampling strategy: what is the basic approach and is it valid?

2.1. We APPROVE the use of the Tropical Soil Biology and Fertility Programme (TSBF) transect and monolith scheme.

This method has evolved from the basic field transect of 40 x 4 m recommended for macrofauna by Anderson and Ingram (1993). The main premises are to have rapid assessment (completing the sampling of a plot in one or two days with only basic equipment and a small number of field assistants), to be able to address all the taxonomic groups at the same time and in the same place, and also to be able to deal with the small plots of fallow and food-crop field which typify tropical subsistence agriculture. We note that the TSBF transect was

designed for the sampling of other soil biota and above-ground vegetation, in addition to macrofauna, and that the spatial scale of the transect is small in relation to the known horizontal heterogeneity of many macrofaunal groups. There may therefore be a case for extending the transect to more than 40 m, and investigators should not feel constrained from doing this where plot size, time and resources permit. However, in all circumstances the minimum transect length should be 40 m, even if this means breaking the transect into parallel fragments. A review of the use of the TSBF transect by Alternatives to Slash and Burn Programme (ASB) is given in Bignell et al. (2000).

There was discussion of alternative sampling strategies, for example casual collection from known microsites and randomized small quadrats, and of alternatives to the TSBF monoliths, for example more numerous small cores, monoliths of different dimensions, large excavations and the application of toxins to drive fauna (esp. earthworms) out of the substratum. While some of these have advantages for specific taxa, their disadvantages are often the same as those associated with transect sampling, with the addition that they may be more difficult to deploy in the field and that horizontal habitat heterogeneity may not be addressed as well as with the use of a transect.

2.2. We RECOMMEND that the number of monoliths per transect is 8-10, as suggested by the original TSBF protocol, but can be increased further as there is some gain of statistical advantage. Similarly, the number of transects can be increased to two or more per plot (but at least 20 m apart) and the separation of monoliths increased from the minimum of 4 m recommended by TSBF.

All regularly spaced samples on a transect are autocorrelated to some extent, and therefore do not constitute independent samples. Optimum spacing is likely to differ from one taxon to another and will also vary with soil type, and while statistical procedures to determine the extent of autocorrelation exist, more than 50 monoliths per plot would be required to employ them. However, there is a case for commissioning a calibration study on the efficiency of transect/monolith sampling, preferably in selected, relatively diverse zones. In such a study, transect sampling at varying transect lengths and monolith separations would be compared with exhaustively sampled actual assemblages and populations. Optimum monolith separations could also be determined for major taxa. Such studies appear to be absent from the literature, but could provide validation for transect methods which currently tend to be employed for historical and logistical reasons rather than from *a priori* scientific principle.

The basic unit of quantitative data collection is the mean abundance or density (units m^{-2}) per transect, averaged across all the monoliths (i.e. one transect is a single sample). However, sampling records should retain details of data from individual monoliths, as these show the variance associated with monolith sampling. It may be useful to report such variance, for example as the 95% confidence intervals associated with a (back-transformed) geometric mean (see Eggleton et al., 1996). However, it should be noted that log transformations do not necessarily normalize abundance and biomass datasets, either within individual transects or between plots with the same treatment.

The basic unit of qualitative sampling is the occurrence (presence/absence) of nominated taxonomic groups, although this may be combined with abundance data to generate diversity indices. For the levels of taxonomic resolution required, see report of the Taxa Group, and for a discussion of the value of diversity indices see the report of the Data Interpretation Group.

2.3. We RECOMMEND that more than 1 plot is sampled per landuse (or zone, or treatment) to avoid pseudoreplication.

3-5 is the optimum number, although this may not be feasible in some localities. Where plot numbers are small, it may be better to reduce the number of treatments (or amalgamate treatments) rather than increase the number of transects per plot, which does not facilitate tests of statistical differences between treatments based on the comparison of variances.

2.4. We RECOMMEND that additional qualitative sampling is carried out on the transect by a) the investigation of microsites within a 2.5 m radius of each monolith and b) by extracting the litter from 1 x 1 m quadrats in Winkler bags.

Microsite investigation should be time-limited; 20-30 minutes per search (for two persons) is suggested as appropriate. Winkler bags are air-dried under cover from rain, a process which extracts ants and beetles efficiently. However the number of samples extracted per transect will depend on the number of bags and the drying facilities available. 3-4 samples per transect are suggested. One sample will require two Winkler bags to dry. There was discussion of the merits of additional qualitative sampling off transect, for example by the use of pitfall traps and by investigating termite and ant mound-nests in an area of approximately 40 x 30 m adjacent to the transect. The arguments in favour of pitfalls are that they sample mobile forms such as ground beetles and spiders, which might otherwise escape during monolith digging; the arguments against are that they are biased in favour of such fauna and are non-quantitative.

The special measures for social insects take account of their high abundance and marked patchiness: a nest could contain millions of individuals, none of which might be sampled by a short transect and the contribution of the species concerned to a macrofaunal assemblage could thus be completely missed. On the other hand, a highly populous nest sampled directly by a monolith could produce a large overestimate of overall numerical or biomass density. In general, the TSBF transect should be placed so as to avoid direct contact with termite and ant nests (but see 3.2. below). For discussions, see Eggleton and Bignell (1995) and Eggleton et al. (1996). The protocol for a 100 x 2 m transect designed to assess termite biodiversity (and feeding group representation) is given by Jones and Eggleton (2000). In suitable circumstances this can also be deployed in parallel with the TSBF transect.

2.5. We RECOMMEND that biogenic structures generated by ants, termites and earthworms (and some other macrofauna) should be assessed on the transect prior to monolith digging and any litter removal.

Protocols for this determination in forests are given by Bernier and Ponge (1994), Bernier, (1996; 1998), and Ponge (1999). Quantification of soil sections is discussed by Bal (1970)

and Jongerius (1963). For agricultural land, modified protocols are given by Topoliantz et al. (2000). This assessment demonstrates the amount of soil processed by ecosystem engineers.

The method consists in cutting off a soil block (5 to 8 cm in section and 10 to15 cm in depth depending on the soil type) with a sharp knife. Each profile is divided in visually homogeneous layers 0.5 to 2 cm thick which are immediately fixed in 90% ethanol. The soil layers are separately spread in Petri dishes filled with 90% ethanol then observed under a dissecting microscope at x40 magnification. The components of the soil matrix are quantified by a point-count method using a transparent grid laid upon the soil layer in alcohol. We obtain the percentage in volume of each component by dividing the number of points above it by the total number of points above solid matter. Concurrently, faeces are identified from soil animal cultures (diplopods, isopods, enchytraeids…).

2.6. Detailed site documentation must accompany sampling. The information required is specified in the Database (see report of Database Group).

3. Sampling tactics: when, where and how?

3.1. We RECOMMEND that sampling takes place at the end of the rainy season (tropics), or (elsewhere) when accessible biodiversity is thought to be greatest.

Large seasonal differences may occur in species diversity, relative abundance and vertical distribution. As a minimum, therefore, the time of sampling should always be reported. Ideally, sampling should be repeated in the same plot under contrasting conditions (for example at the beginning of the wet season, to evaluate the impact of drought on communities)

3.2. We APPROVE stratified sampling where this is appropriate to a major topographical or vegetational feature of a zone or plot, or where the distribution of macrofauna is expected to be highly clumped.

We ACKNOWLEDGE that protocols cannot be prescriptive on the positioning of transects, owing to differences in plot size and shape, and to variations in vegetational patterns, especially clumping of grasses and trees. Little or no guidance exists in the literature, other than that transects should include the major plot heterogeneities of interest (for example upper and lower slopes, under trees and between trees, in tussocks and between tussocks, in crop rows and between crop rows, etc.) and should avoid features which are likely to contain none of the organisms being addressed (steep gullies or cliffs, streams, waterlogged ground, fresh skid trails etc.) However, the transect can incorporate other natural features of the environment which seems likely to contribute to its biological heterogeneity, such as dips, dry stream gullies or small canopy gaps. Some subjective judgement is often necessary to decide on the most suitable line, especially where the treatment plots concerned are small. Transect lines do not need to be absolutely linear, and can be turned through angles of up to 90^{o} to avoid natural obstacles, for example large tree trunks, as long as they do not re-intersect with themselves. In small plots a transect can be turned, successively, through two 90^{o} angles to

run back towards the starting point, but the two main "arms" of the transect should be at least 20m distant. Alternatively, two half transects can be run in parallel. It is advisable to make a note of the starting point, initial compass bearing of the transect line and any major directional changes. If two 40 x 5m transects are employed for replicated monolith and other sampling, other qualitative sampling such as a 100 m termite transect should run between them, but allowing sufficient space to avoid mutual interference.

Stratified sampling might include the division of a transect into two 20 m halves, one placed in a particular type of vegetation patch and the other in a second, or might include the special sampling of an under-tree soil on or off the transect, combined with a conventional row of monoliths between trees. In more complex versions, especially those designed for social insects, the soil might be sampled by transect monoliths while large woody items and mound-nests on or off the transect are considered as special cases and destructively sampled to collect all associated animals. In yet other cases, for example where soil is highly populated and litter less so, the sampling unit for hand-sorted litter might be a larger area (say $1m^2$) than for monolith soil (0.0625 m^2 is standard), while mounds are sampled destructively over a large adjacent area (e.g. 400 m^2). For termites in tropical forests, investigation of the surface 10 cm of soil is usually more productive of specimens than sorting lower horizons. This can be made quantitative by digging out several small blocks (10 x 10 x 5 cm) within a quadrat of 1 m^2, in addition to excavating the monolith (Eggleton et al., 1996).

In summary, it is important to make a subjective assessment of the scale of heterogeneity in any plot. Heterogeneity on the cm or metre scale can be accommodated by the basic transect, but heterogeneity in units greater than ca. 10 m, or on a landscape scale, may require the introduction of a stratified sampling regime.

3.3. The following items of basic equipment are recommended.

Tapes measures of 30 m and 10 m, machette (cutlass or parang), spade, plastic weave produce sacks for spreading on the ground, large flat plastic traps (50 x 40 x 10 cm) for sorting the soil and litter, trowel, small plastic trays, fine forceps (or entomological forceps), fine paint brushes, sample vials in various sizes with secure alcohol-tight caps, Indian-ink pen (waterproof), stiff card for labels, notebook, ranging compass, large strong plastic bags (sealable), table and plastic chairs (for sorting), tarpaulin (for protection from heavy rain).

Both 80% alcohol and 4% formalin should be available for preservation of specimens (4% formalin is more suitable for earthworms, which can be transferred to alcohol after about 4 days fixation).

The use of metal frames, which are driven into the ground with a sledgehammer to cut the monolith quickly, are recommended by some authors. It is claimed that these prevent the escape of rapidly moving animals (some earthworms, termites in large subterranean galleries). However, frames have to be specially modified to permit the monolith to be rapidly divided into 10 cm strata (usually one side of the frame is detachable, or incorporates horizontal slits for the insertion of separators). A useful alternative is to use metal frames 5 cm high that delimit the sample and facilitate further cutting.

4. Sorting and extraction

4.1. *We RECOMMEND that all material from each stratum of each monolith is hand sorted in the field without time limitation.*

Hand sorting is widely assumed to be subject to error and inefficiency, but this is likely to vary between season and taxonomic group and with body size and soil type. Field assistants should collect all taxa (i.e. not specialize), although ants should be picked out first, as they have a tendency to escape. This error, however is accepted since the objective is to collect fully standardised and comparable data sets rather than complete extractions. Although some data are available in the literature (Lavelle and Kohlmann, 1984; Jimenez-Jaen, 1999), we believe a study of hand sorting efficiency for different taxonomic groups should be carried out to validate the TSBF method.

4.2. *We RECOMMEND that all digging, sorting and extraction tasks are rotated between field assistants to minimize biases.*

5. Biomass determinations

We RECOMMEND the use of fresh weight, measured in the field. Failing thiswe accept that blotted weight, after preservation, may be substituted.

Other methods are reported in the literature, for example fresh weight after blotting, dry weight at 60^{o}C overnight, drying to constant weight at higher temperatures, degutted fresh weight, degutted dry weight, fresh weight x a constant (for assumed water content) and head width (referenced to a calibration curve). However, we argue these have less biological meaning than fresh weight. As a minimum, the method of determination must always be specified.

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Group 2 : Taxonomy

Group members :

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Introduction. We set out to produce a framework for taxonomic activities under the umbrella of the MACROFAUNA project. Such a framework is required not only for subsequently sampled datasets, but also for the development of a website. This document is a summary of our discussions and proposals.

Our general approach has been to define minimum standards for taxonomic practice. Beyond that we favour a modular approach, adding additional taxonomic resolution as it becomes practicable especially for groups which are numerically important.

Definitions. The term 'soil macrofauna' has not been well defined. For the purposes of this project we will define it at a higher taxonomic level using the broad criterion that :

'A soil macrofauna taxon is an invertebrate group found within terrestrial soil samples which has more than 90% of its specimens in such samples visible to the naked eye'

This definition specifically excludes groups with a relatively small number of specimens which are visible to the naked eye such as Nematoda (e.g. Mermithidae), Enchytraeidae, Collembola, Acarina, Symphyla, Pauropoda, and Diplura. Also excluded are taxa that although relatively large are usually extremely uncommon in most soil samples (Onychophora, Thysanura, other insect groups). Note that large bodied Enchytraeidae may reach high biomass densities in some cool temperate and boreal regions and they may therefore need to be included in biomass estimates for specific sites.

Standardisation of taxonomic units. There are a large number of macrofaunal taxonomic groups found in the soil. However , the identification of all such groups would : (i) be difficult to teach effectively, especially across a website, (ii) be excessively time consuming, and (iii) cause major data storage and handling difficulties, especially with respect to the central database. For these reasons we decided to fix on a number of core taxonomic units that we felt should be adopted as standard units for macrofaunal sampling. We have used preliminary data from the MACROFAUNA database (200 samples from mostly tropical regions) to assess the relative importance of macrofaunal groups at a global level (Table 1) and therefore to guide us in our choice of taxa. The striking result of this

preliminary analysis is that almost 95% of both soil macrofaunal biomass and abundance is in just six groups (earthworms, beetles, termites, centipedes, millipedes and ants - the critical taxa below).

Table 1. The 17 core taxa and their relative contributions to biomass and density across the MACROFAUNA database (as of 22/06/2000). Superscripts refer specifically to the core taxa. The critical taxa are the six taxa above the double line. Note that some critical taxa have not been sorted separately in the MACROFAUNA dataset so far.

Core Taxon	**Biomass (%)**	**Density (%)**
Oligochaeta opisthopora[1]	74.43	9.85
Coleoptera (larvae and adults)[2]	6.89	3.32
Isoptera[3]	6.30	49.15
Myriapoda (Diplopoda[4] and Chilopoda[5])	5.23	3.27
Formicidae[6]	2.65	29.28
Gasteropoda[7]	1.30	0.49
Aranaea[8]	1.00	1.17
Blattoidea[9]	0.64	0.19
Orthoptera[10]	0.38	0.08
Dermaptera[11]	0.27	0.51
Isopoda[12]	0.26	0.96
Hemiptera[13]	0.22	0.13
Lepidoptera larvae[14]	0.21	0.20
Diptera (larvae and adults)[15]	0.17	0.39
Residues (Insects[16] and non-insects[17])	1.26	1.00

Once these core taxa have been agreed upon they must, obviously, be utilised absolutely rigidly especially as regard to their taxonomic limits. Here is one example to emphasise the point. In many studies the polyphyletic group Myriapoda has been employed : this group is not acceptable as it combines two of our core taxa (Diplopoda and Chilopoda).

Key to core taxa. We concluded that a simple key was required to allow quick separation of the core taxa. This key will :

1. Derive initially from an existing macrofauna key (possibility the key of Goeffroy).
2. Be initially a standard dichotomous key, but may eventually be a multi-access interactive key. However, this will require some development time.

3. The key will be in English on the website, but should be translated (at least) into Spanish, French and Portugese in any field manual

4. The key should be extensively illustrated with photographs and drawings of the taxa. The commonest taxa found in the residues (see [5] below) should also be illustrated. The problem of different life stages and castes (social insects) will have to be addressed in the key.

5. The key should be designed so that the residual (unidentified) specimens are placed in one of two clearly defined categories ('other insects' and 'other non-insects'). These categories are intended to provide a safety check against either (i) misidentification or, (ii) the existence of groups that are unusually abundant in the samples. We suggest that if either residue contains more than 5% of the total faunal biomass then this will require a re-identification of the residue material, and possibly a request for expert help.

Level of taxonomic sorting.

We discussed this problem in some detail:

1. We agreed that the ideal was to sort to real (i.e. described) species, but that constraints on time and taxonomic expertise made this impossible.

2. We also agreed that morphospecies sorting in the absence of expert help or detailed training is likely to lead to serious underestimates of actual species diversity. Preliminary data on species sorting of termites in Africa suggest underestimates of roughly 300% in some datasets.

3.In the absence of true species sorting, however, we saw the clear value of sorting to lower taxonomic levels wherever possible. We felt especially that sorting to genus (and some higher taxonomic units) would represent a good compromise between the morphospecies and ordinal level approaches, especially as this would allow most specimens to be assigned to a functional group.

4. We felt that taxon-specific morphospecies-level taxonomic skills can only be taught by taxonomic experts and that there is a pressing need for taxonomic workshops teaching such skills, especially for the critical taxa. We propose that funding should be sought to set up workshops for earthworms (Mexico, Spain?) and termites (London ?) in the first instance.

Preservation and curation of specimens.

From any mixed soil sample of macrofauna, the following steps should be followed in order to obtain standardised preserved specimens :

1. If the animal is not an earthworm, the organism should be preserved in ethanol 80% (commercial alcohol should be diluted). Higher concentrations of alcohol (c. 90-95%) are advised in very hot climates where alcohol evaporation can be a problem.

2. If the animal is an earthworm, the organism should be fixed in 4% formalin (known also as formol), and if possible should be preserved in 4% although ethanol 80% could also be used.

3. In ALL cases, samples should be kept separated in different vials, according to the smallest unit of analysis(i.e. a monolith if the data will be compared at that level).

4. EVERY VIAL should be labelled without using code numbers, and at least should be written using permanent ink like, India or China ink, and using sturdy paper, like goastskin parchment paper. If labels are obtained directly from the website, then only specialised printer ink should be used to print them out. Every label should contain the following information (refer to database for meaning of codes *) :

- Country
- Zone *
- Locality *
- Collector's name
- Date of collection

5. For storing the specimens :

- Use sturdy vials (will not be degraded by the alcohol or formalin) with screw caps
- Monitor levels of alcohol and formalin in order to keep it constant
- Store vials out from direct sunlight
- Change the preserving solution from every vial once every five years.

6. Specimems from the vials should be sorted to a taxonomic level and sent to the taxonomist according to expert's requirement (for example in alcohol or pinned, by ordinary mail or courier service, in envelope or box, etc.).

7. Material should be catalogued in the website, in trems of : who is identifying the samples, where is the material at different steps of the identification process, who requested the identification and who owns the specimens. There should be a

button/link to fill this information and that will also allow the database manager to keep track of the specimens.

Relationship with taxonomic experts. Taxonomist with expertise on the five critical taxa (in the first instance) should be contacted and arrangements should be made to agree upon specimens' identifications. After finding these candidates their names should be listed (see section 7).

Three different aspects should be considered in this section.

1. Minimum work required by the collector in order to enter the data at the database of the website. This includes :

- Sorting the specimems to core taxa from those vials which have been separated into the smallest unit of analyses (section 5, item 3).
- Count all the individuals sorted into the core taxa.
- Obtain biomass from a sub-sample of the counted individuals.

2. Minimum work required by the collector to meet the needs of the expert who is going to identify the core taxa. This could include sorting the material to families or morphospecies depending upon the taxonomist requirements.

3. Minimum list of items that the taxonomist should agree upon and include under his/her name at the website. It should include :

- e-mail and Institution/Country
- Time available for identification
- Time frame for identification
- Preservation instructions, if different from listed in section 5
- Sorting level desired
- Cost of identificationper vial or specimen
- Fate of material at different stages of identification
- Taxonomical/regional groups willing to be identified within his/her critical taxa expertise
- Notes

Website and database considerations. We highlight the following important areas :

1. The key to core taxa should be prominent on the website and should be linked to a secondary level of taxonomic and biological information on each group (probably at the order/family level depending on the initial taxonomic level of the core taxon concerned). This secondary level should then be extensively linked to taxonomic resources (websites, experts, bibliography) for the core taxa.
2. The website databases should include the list of taxonomic experts for each of the core taxa as stated above ; it should be specified if specimens can be identified at a global scale or only for some biomes or geographical places.
3. The website should provide a conduit to allow data on new species to get to the central database, so that over time (and initially only for the critical taxa) the database can develop at the species level as well as at higher levels.
4. Special consideration should be given to the different needs, requirements and priorities of those contributing to the database. Questions of intellectual property rights, specimen ownership, and authorships of papers emerging from analyses of the central database will be of particular importance. Finding new taxa may introduce specific aspects of ownership that should be stated and discussed either as a general rule for those contributing to this website or by personal agreements with each specialist.
5. It is recommended that an evaluation system could be organized, at different steps of what has been proposed here, in order to evaluate the efficiency of the taxonomical process.

Group 3 : The Macrofauna database

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History of the Macrofauna database

The origin of the Macrofauna database (MDB) can be traced to the year 1990 when the EC project "Management of earthworms in tropical agroecosystems" was launched at Vaison La Romaine, France. The main objective at that time was to construct a database to store information of earthworm species and communities from different tropical countries of the world. The database was designed, since the beginning, as a relational database with several tables related by a common field. In the old DBASE IV format, this database contained seven tables-files with information about the name and taxonomic position of species (EWTAX), climate and geographic localization of sites (EWCLIMA), edaphic and agronomic features of sites-land use systems (EWSOILVEG), attributes of population (EWPOP) and communities (EWCOMM), information on other macrofaunal groups found (EWMACROF) and a file with literature references of the stored data (EWBIBL). In 1993 in a meeting held in Orsay, France, it was decided to add the EWSOCEC file in order to store economical and social information of tropical farmers linked with the experiments and earthworm samplings of this project, including some information about their perception and beliefs about macrofauna (mainly earthworms) influences on soil fertility.

In 1991, during a TSBF meeting in Martinique, France, a first analysis of tropical macrofauna revealed important patterns of distribution for some groups of organisms in most natural and managed Land Use Systems from different tropical countries:
i) earthworms dominated macrofaunal biomass,
ii) abundance dominance by ants and termites, and
iii) the elevated biomass of macrofauna (due to earthworms) in pastures and savannas (Lavelle et al. 1994).

After this first analysis, MDB was subsequently mainly managed to obtain information on earthworms (Lavelle et al 1999), with some analysis of particular macrofaunal distribution patterns (e.g. acid soils influence, Lavelle et al 1995). Still maintaining the DBASE format (*.dbf) management since 1993 was done with PARADOX program.

In 1999 MDB migrated to ACCESS, but the basic structure (seven related tables) was maintained. At the beginning of 2000 other modifications were done to MDB in order to store information about sampling procedures. The MDB included at the beginning of this meeting the following tables:
i) Site sampling,
ii) Soil-vegetation,
iii) Geographic and climate,
iv) Macrofauna abundance,
v) Macrofauna biomass,
vi) Macrofauna vertical distribution,
vii) Collection and
viii) References.

Accordingly participants of this meeting provided new data to MDB following this last format.

Objectives

During the recompilation of data it was soon evident that the current structure of the MDB would need modifications; on the other hand it was also realized that the task of obtaining and capturing data to feed MDB would also need a lot of work. Consequently the main objectives of this working group during the four days of the meeting were:

1) To modify the current structure of the MDB in order to make simplest the feeding in of data and to leave open the possibility of introducing other kinds of data (e.g. monolith data)
2) To make sure that data from all participants were stored in MDB

Current structure and proposed modifications

Some months before this meeting most of the participants received two files that contained the seven tables of MDB. The aim was that each participant would store their macrofauna data, according to this format. The first file was an ACCESS file with seven empty tables, whereas the second one was an Excel file with seven empty sheets.

During the meeting this working group obtained from each participant their data (in Access or in Excel format), and then we integrated all data in a single file in ACESS format. It was also discussed and decided that:

1) MDB Efficiency: ACCESS should be maintained, but in the future it will be open to the possibility of migrating to another more efficient software (e.g. ORACLE).
2) MDB Simplification: Once all data has been stored, some fields will be removed.
3) MDB Improvement: Modification of MDB is necessary in order to improve both the storage and retrieval of data (e.g. addition of catalogs, dictionaries linked to specific fields, etc).
4) MDB Availability: MDB should be available to scientific community in our IBOY Programme Web page. Thus manager of MDB should be closely linked to this web

site. At the beginning, passwords should be used by members of this programme to check their own data and provide modifications to the MDB manager.

Following we present the ACCESS current structure of MDB including definitions of tables and fields.

Table 1 : Site-Sampling data ***:*** Contains information about the sampling method used for specific data.
Fields
NoLocality: A number that identifies the geographic localization and the climate of zones. One locality can contain more than one zone.
*Zone: A number that identifies the zone-soil type sampled. The difference with the former field is that the same zone can be sampled in a different date or with different methods. Therefore a zone can contain more than one sample.
Sample: A number that identifies the date and method of sampling. This number can not be repited .
Collection: A number that identifies the Institution where the material is deposited.
Method: indicates if TSBF or other method was used, discriminating between transects vs. Random sampling.
Monolith number: Number of monoliths used to obtain averages of macrofauna values.
Monolith size: Size (in m^2) of monoliths.
Monolith depth: maximal depth in cm.
Number and size of strata:
Season: dry or rainy indicating the month of sampling in brackets.
Collector: name of the collector of the sample
Reference: a number that identifies the paper in which all or part of the data of each record was published.

Table 2 : Soil-Vegetation characteristics ***:*** Contains information about soils and land use systems (inputs, management, etc).
Zone: A number that identifies the zone-soil type sampled.
Site description: localization of the zone.
Soil type: According to FAO (i.e. vertisols, regosols, etc).
pH: determined in H_2O
*pF42: wilting point, expressed in % of moisture
*pF28: field capacity, expressed in % of moisture
Moisture: % of moisture when sampling was made (0-10 cm depth)
Org.matter: % of organic matter (0-10 cm depth)
Nitrogen: % of nitrogen (0-10 cm depth)
Calcium: Ca contents of first 10 cm depth (in meq/100 g)
Magnesium: Mg contents of first 10 cm depth (in meq/100 g)
CEC: Cation exchange capacity of first 10 cm depth (in meq/100 g)
P: phosphorous determination of first 10 cm depth (in)
Texture: texture type of A horizon
Sand: % of sands of first 10 cm depth
Clay: % of clays of first 10 cm depth

Silt: % of silt of first 10 cm depth
Stones: qualitative description of the amount of stones in the monoliths (few, medium, several)
Temperature: soil temperature of first 10 cm depth
Roots: average biomass of roots (g/m^2) of qualitative description)
Litter: average biomass of surface litter (g/m^2)
Topography: flat, irregular or slope
Slope: degrees of slope
Slope orientation: orientation and degree of moisture (i.e. NW humid)
Vegetation: N or M (natural or managed)
Vegetation type: kind of vegetation type followed in brackets by the subtype.

The following fields applied only to managed sites:
Tillage: yes or no
Pesticides: yes or no
Kind of pesticides: kind and amount of pesticides (in kg/ha)
Fertilizers: Kind and amount of fertilizers (in kg/ha)
Age of perturbation: time elapsed (in years) since first perturbation (this applies also to fallows)
Former vegetation: former types of vegetation with amount of years in brackets.
Reference: a number that identifies the paper in which all or part of the data of each record was published.

Table3 : Geographic and climatic characteristics : It contains information about the climatic and geographic localization of localities.

NoLocality: A number that identifies the geographic localization and the climate of zones
Country: In capitals
State or Province:
Locality: Local name of the town or place where sampling was made
Altitude: in meters over sea level
Latitude: in degrees, minutes and seconds
Longitude: in degrees, minutes and seconds
Climate: Description according to Koepen systems (i.e. hot subhumid)
*Climate formula: According to Koepen system (i.e. Am»(i)g)
Rainfall: Annual rainfall in mm.
Drymonths: Number of dry months (less than 100 mm/month)
Avanntem: Average annual temperature (in Celsius degrees)
Reference: a number that identifies the paper in which all or part of the data of each record was published.

Table 4 . Macrofauna Abundance : Contains information about abundance of groups.
Sample: A number that identifies the date and method of sampling.
Totd: Average abundance of macrofauna (from monoliths), including all groups and all strata (in ind/m^2).

Each one of the following groups, that generally account more than 1% to total abundance and biomass, correspond to a single file (average abundances from monolithes-ind/m^2)
EwD=earthworms, TerD=termites, AntD=ants, ColeopD= coleoptera adults, ArachD=spiders (only Arachnida), MyriaD= myriapods, DiplopD= Diplopods, QuiloD=quilopods, IsopD= isopods, DipD= diptera, adults and larvae, BlatD= cockroaches, HemipD= hemiptera, LlepidoD= lepidoptera larvae, OrthopD= orthoptera, GasteropD=gasteropoda, DermapD= Dermaptera, OthersD= include all extant groups with less than 1% from total abundance or biomass.
Reference: a number that identifies the paper in which all or part of the data of each record was published.

Table 5 : Macrofauna Biomass **:** Contains information about biomass of groups.
Sample: A number that identifies the date and method of sampling.
Totb: Average biomass of macrofauna (from monoliths), including all groups and all strata (in g/m^2)
Each one of the following groups, that generally account more than 1% to total abundance and biomass, correspond to a single file (average biomass from monolithes-g/m^2)
EwB=earthworms, TerB=termites, AntB=ants, ColeopB= coleoptera adults, ArachB=spiders (only Arachnida), MyriaB= myriapods, DiplopB= Diplopods, QuiloB=quilopods, IsopB= isopods, DipB= diptera, adults and larvae, BlatB= cockroaches, HemipB= hemiptera, LlepidoB= lepidoptera larvae, OrthopB= orthoptera, GasteropB=gasteropoda, DermapB= Dermaptera, OthersB= include all extant groups with less than 1% from total abundance or biomass.
Reference: a number that identifies the paper in which all or part of the data of each record was published.

Table 6 : Macrofauna Vertical distribution **:** Contains information about vertical distribution within the soil profile of groups.
Sample: A number that identifies the date and method of sampling.
Totvertdistr: the total % of individuals in the 0-10,10-20-20-30 and 30-40 stratum.
Each one of the following groups, that generally account more than 1% to total abundance and biomass, correspond to a single file (% of individuals from each 10 cm layer expressed as values separted by comma), EwVD=earthworms, TerVD=termites, AntVD=ants, ColeopVD= coleoptera adults, ArachVD=spiders (only Arachnida), MyriaVD= myriapods, DiplopVD= Diplopods, QuiloVD=quilopods, IsopVD= isopods, DipVD= diptera, adults and larvae, BlatVD= cockroaches, HemipVD= hemiptera, LlepidoVD= lepidoptera larvae, OrthopVD= orthoptera, GasteropVD=gasteropoda, DermapVD= Dermaptera, OthersVD= include all extant groups with less than 1% from total abundance or biomass.
Nogroups: Total number of groups found in all monoliths, including those which account less than 1% to total abundance and biomass.
Reference: a number that identifies the paper in which all or part of the data of each record was published.

Table 7: Collection **:** Address and name of the curator in charge of the collection
Collection: A number that identifies the Institution where the material is deposited.
Institution: Name of the Institution in which the material is deposited

Address: Address of the Institution
Curator: Name of the curator in charge of the collection
Telephone - Fax - e-mail.

Table 8. References :
Reference: a number that identifies the paper in which was published the data stored in different tables.
Author: Name of first author plus et. al., if corresponded
Year: year of publication
Paper: complete reference. For papers: author(s), year, title, Journal, volume, number (in brackets), pages; for books: author(s), year, title, editorial, city, pages; for book chapters: author(s), year, title, pages, editors, title of the book, editorial, city, total pages of the book.

After analysing this current structure, some modification were decided during this workshop, mainly:

1. removal of several fields (marked with * in previous tables)
2. Separation of data in more specific groups (e.g. Coleoptera data should be split into larvae and adults)
3. Addition of new tables for specific groups, for which information at the species level is available . For example, for earthworm species the following tables can be added:

Table 9 PopulationEW. :
Table which will include information about the species level (abundance, biomass,vertical distribution, ecological category), including the following fields : Sample: A number that identifies the date and method of sampling. Spew: a number that identifies the name and classification of the species. Abundew: abundance in ind/m^2 (average of all monolithes and strata) Biomew: biomass in ind/m^2 (average of all monolithes and strata) Vertdstew: vertical distribution, % for 0-10,10-20, 20-30, 30-40 strata. Ecolcatew: ecological category of the species. Originew: Biogeographic origin of the species: native or exotic. Reference: a number that identifies the paper in which all or part of the data of each record was published.

Table 10 Taxew. : Table with information about the name and classification of the species, including the following fields: Spew: a number that identifies the name and classification of the species. Genus, Species, Family, Subfamily, Tribe, Reference.
It was discussed that for more detailed statistical analysis, and for some specific sets of data, separation of data at the monolith level could be necessary. However this action will be implemented next year, once authors of data agree to share their data at this level.

*= fields removed during meeting

Present Status of the Data in the Base

At present, data has been entered into bases in either EXCEL or ACCESS for 32 countries and over 100 sites. The total number of samples taken for which average

density and/or biomass is available exceeds 560 (Table 5).

Nevertheless:

- not all data have the same format
- the quality of the data in terms of their completeness is greatly heterogeneous.
- much of the data that is available has still not been collated into the database.

Thus at present the data and the database are still under-developed and its potential uses remain highly limited.

The format of the database is still under debate and a final decision will soon be made so that all the data can be joined and placed into one database and format. There are many reasons for the difficulty in establishing standard formats for the database. One of the main reasons is the extremely heterogeneous nature of the collections and collection situations, the availability of different resources to the collectors, and the priorities set at the moment of collection, identification and final reporting of the data. Consequently, many of the presently proposed and previous fields of data within the database are not available for all sites.

Regarding the above comments we can make the following recommendations.

RECOMMENDATION 1

It is necessary that a person be hired part or full-time to take on the task of database management, and that funds be secured to have continued management of the database throughout the project duration and beyond.

RECOMMENDATION 2

It is essential that the database standard format be agreed upon by all participants and potential data providers and that the available data within the database be put into a standard format as soon as possible.

For the database to be used by the participants and other interested users, it must be clear to everyone who accesses the base what kind of data is available in each of the tables. Similarly, those who will be contributing to the database must be able to recognize what each of the fields of the tables represents, so that the proper bits of data (information) are entered into each field, and in a standardized format. This will prevent confusion among the contributors to the database as to what goes where. For example, at present there is still not a well defined list of vegetation categories that will allow separation of sites according to vegetation.

RECOMMENDATION 3

A dictionary with the definition of each of the field titles of the different datasheets within the base should be elaborated, to adequately explain and clarify the format and data which should be entered into each data field.

Much of the data which is presently available and data which will be entered into the database has not yet been published. This creates a problem of intellectual property rights and risks of abuse by future database users, who may decide to publish data without adequately citing the sources. There are two potential solutions, both of which we recommend be taken.

RECOMMENDATION 4

A formal agreement of the rules and codes of conduct for the use of the database among users and project participants should be developed and included as a first step in accessing the database.

This agreement would appear before being able to access the database so that anyone wishing to use it must promise to adhere to a certain ethical code which includes proper citation and recognition of original data providers. If they refuse, they are not able to use the database, and if anyone is discovered to breach this agreement, they would be warned of eventual legal consequences. Furthermore, it should be suggested that any large reviews or important uses of the data be consulted with or authorized by the original data-holders, as a sign of respect for their efforts.

RECOMMENDATION 5

Passwords should be developed for restricting the access to more important parts of the database such as its functioning structure and for reducing potential for fraudulent activities.

These passwords would protect the database from being misused or data from being altered by external users who are not authorized to change particular components of the database. This is an essential action, particularly since the database will be made available over the internet and accessible by millions of people all over the world.

RECOMMENDATION 6

We suggest that the database manager work closely with the person responsible for making the database available over the internet.

This is to ensure that the many issues which will be raised in the accessibility of data and the potential uses be adequately coordinated to create a user-friendly, easily accessible, yet protected database.

Table 5. Data on macrofauna biomass and abundance in different continents and countries, available in spreadsheets and in the database. Numbers with a > sign next to them represent countries where not all the available data has yet been entered into the computer and/or where sampling is currently being undertaken and it is expected that more data will become available during the year 2000.

Continent /**Country**	**Sites**	**Number of zones**
Oceania		
AUSTRALIA	Narayen	3
Asia		
INDIA	Attikuna, Carolyn, Iyerpadi, Kogar, Parlai, Sikalmudi, Murugalli, Tura, Nilambur	46
MALAYSIA	Pasoh, Gunnung Sila	18
REUNION		
SARAWAK	Gunnung Mulu	4
SRI LANKA	Eladuwa, Sinharaja	2
Africa		
BENIN	Agonkamey	3
BURKINA FASO		
CAMEROON	Gazad, Akokas, Awae, Nkolfulu	>23
CONGO	Dimonika, Pointe Noire, Loudima, Mayombe, Mouyondzi, Manlsouba, Sari, Niari	>27
IVORY COAST	Bimbresso, Booro-Boroto, Ferke, Foro, Lamto	>33
KENYA	Kabras, Surungai, Kakamega	>10
SENEGAL	Kolda, Thysse	>24
SOUTH AFRICA	Nylsvley	2
TANZANIA	Ihenge, Kibedya, Maguha, Rubeho	6
UGANDA	Mabira	4
ZAIRE	Kasamba, Kimwenza, Kinzambi, Kumbi, Munekantebi	8
ZAMBIA	Kaka, Nsokolo	16
ZIMBABWE	Murewa, Marondera	24
Central America and Caribbean		
CUBA	Cangrejeras, Santiago Vegas, S. Diego Baños, Sierra Rosario	10
COSTA RICA	Volcán Barva	2
DOMINICA	Grand Fond	2
GUADALUPE	Duclos, May	7
MARTINIQUE	Ste. Anne, Rivière-Lézarde	10
PUERTO RICO	Luquillo	2
South America		
ARGENTINA	Mercedes	5
BRAZIL	INPA, Manaus, Sta. Helena, Itabela, Londrina, Passo Fundo	>30
COLOMBIA	Cabuval, Carimagua, Matazul	26

Table 5. Continued

***Continent*/Country**	**Sites**	**Number of zones**
GUYANNE		
PERU	Yurimaguas, Pucallpa	22
North America		
MEXICO	Reforma, Sian ka'an, Huimanguillo, Gómez Farías, Alborada, Bella Esperanza, Buenavista, Coatepec, Perote, Carranza, Isla, La Mancha, La Víbora, Negritos, Los Tuxtlas, Martínez de la Torre, Medellin, Paso del Toro, Plan de Hidalgo, Salinas, San Marcos, Teocelo, Tuxpan, Acayucan, Bonampak, Cardenas, Chajul, Jaltipan, Magallanes, Ocotal, Saltillo, Palma Sola, Plan de las Hayas	>144
Europe		
FRANCE	Rouen	>6
TOTAL	**>100 sites**	**>560**

Data available according to different categories

1. Continents and countries:

Soil macrofauna communities have been sampled in all of the main continents of the world, except Antarctica. However, one can easily observe from the results displayed in Table 5 that there are many regions that are under-represented and have not yet been sampled using this methodology. Data on various groups may be available, but data for the macrofauna communities, as defined in the TSBF methodology, is not available.

For example:

- in Oceania, only one site in Australia has been sampled
- in Asia, only in India have a large number of samples been taken, and in Malaysia, only in tropical rainforest
- 13 African countries have been sampled, ranging from wet to drier regions. However, in many of these countries only localized samples (one site) have been taken, so knowledge is far from comprehensive

- 4 Caribbean islands have been sampled, yet many more remain untouched. In Costa Rica only one site was sampled
- in south America, a few sites in Colombia, Peru and Brazil have been well studied but much more still needs to be done
- of all the countries studied, Mexico has been the most sampled, yet the samples were concentrated on the Eastern side, particularly in the State of Veracruz. No data is available for the drier regions, and only two mountainous sites have been sampled. The other countries in North America have still not been sampled.
- Europe is highly under-represented. This is primarily because the methodology was developed for tropical regions. Nevertheless, the potential for use even in temperate regions is high, and more efforts should be undertaken to publicize, test and apply the TSBF method and in temperate climate countries.

2. Vegetation types :

At present, a standard format for presenting different vegetation is still not available. This means that the information in the table below is only tentative, and will be changed once the standard format is decided upon. As mentioned above in recommendation 3, the standardization of vegetation types will allow a proper evaluation (even if preliminary) of the status of different macrofauna groups present under the different vegetation types.

As of June 2000, it appeared that the vast majority of the samples had been taken in pastures and forests of different types (Table 6). A few types of vegetation, particularly crops, had only a very limited number of samples (e.g., sunflower, sweet potato, rice), while others such as maize and sorghum had a larger number of samples. Tree crops such as citrus, coffee, tea and rubber had a relatively similar number of samples, however, these were taken in geographically restricted areas, mostly in a single country and region. An adequate representation of various vegetation types throughout different regions, countries and continents would be an ideal situation for a more powerful analysis of the presence of macrofauna groups according to land use practices.

Table 6. Separation of available data (number of samples) in database as of June 2000, into main vegetation types, as provided in the field of vegetation type, in the soil-vegetation table.

Main vegetation types	Number samples
Pastures	118
Forests (primary, secondary, pine, tropical rainforest, sub-deciduous, etc.)	74
Miombo woodland	5
Fallow	52
Savannas (tree, shrub, palm, grass) and grasslands	30
Tree plantations (timber trees, rubber, tea, coffee, citrus, etc.)	50
Maize	26
Other crops (sugarcane, millet, rice, peanuts, sunflower, sweet potato, cassava, etc.)	46

3. Annual rainfall

Table 7 shows the distribution of sites according to annual rainfall regimes. Most of the sites were located in regions with rainfall between 1000-2000mm. Fewer sites were sampled with low rainfall, and the samples seemed in general biased toward areas with larger amounts of annual rainfall.

Table 7. Distribution of sites according to annual rainfall regimes, taken from data base as of June 2000.

Annual rainfall regimes (mm)	Number of sites
<1000	12
1000-2000	38
2000-3000	19
>3000	19

Perspectives for present use, limitations and future needs:

The current perspectives for use of the database are very limited, but when it is finished, all the data is all entered, standardized and made available to all users, the potential uses of the database are immense.

Statistical analyses of various kinds can be undertaken and local, regional, national and global patterns of macrofauna distribution assessed, according to a wide range of

variables within the data base. The more information that is entered into the database, the more powerful the analyses that can be performed.

Once the data are ready to analyze, it will be important to immediately assess which country regions, climate zones, vegetation and soil types, altitudes, etc. are under-represented, to determine sampling priorities for the future. Furthermore, various distribution patterns can be obtained and hypotheses for further confirmation and sampling and other actions proposed, such as the assessment of immediate conservation and/or management needs.

During the meeting, a proposal was made by the data analysis group that all the data be entered at monolith level, not just means of the monoliths for each sample location. For this to be made possible, it must first be agreed by all participants that they are willing to give their original data tables and next, the data manager for the database must spend an enormous amount of time to re-format and re-enter the data into the database. Given that data is being managed at a much more specific level, and an immensely larger amount of data is being managed (at least 5-10 times more numbers...), the risks of mistakes become proportionately larger. Furthermore, not all the data presently entered into the database comes from participants in IBOY and much of the data on the individual monoliths will not be available in the literature. It must be seriously discussed further, whether this option is really feasible.

Secondly, the participants debated as to whether data should be entered by strata, be it the means for all samples or for each monolith. This would permit an adequate characterization of the horizontal and vertical distributions of the organisms in the soil and sample locations. These cannot be deduced without the complete data sets. The main problem with this is that as for above, not all data for the strata is available. For those participating in IBOY, these are available, but for older data from the literature, these will be difficult to obtain. Furthermore, this would increase the workload of the data manager.

References:

Lavelle, P., Dangerfield, M., Fragoso, C., Eschenbrenner, V., López-Hernández, D,. Pashanasi, B. and Brussaard, L. (1994) The relationship between soil macrofauna and tropical soil fertility. In *The biological management of tropical soil fertility*, eds P.L. Woomer and M.J. Swift, pp. 137-169. John Wiley & Sons, Chichester.

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Lavelle, P., Brussaard L. and Hendrix, P.F. (1999) *Earthworm management in tropical agroecosystems*. (eds.) CAB International, Wallingford.

Group 4 : Treatment of data

Group members :

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Thibaud Decaëns (Reporter)
Juan Jose Jiménez
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Bikram Senapati
Ichiro Tayasu

The first task assigned to our working group was to propose a list of current statistical analysis and a list of softwares available for both PC and Macintosh computers. The second step was to perform multivariate analysis with the MACROFAUNA database. At this time, the database is not ready and only the description of multivariate analysis is presented in this report.

Basic package of techniques: dealing with means and variances

Basic statistics such as mean comparison are somewhat problematic with soil fauna data since most of the data sets display strong aggregation (i.e. high variance to mean ratio). In that case frequency distributions are skewed and hence the normality assumptions are not met.

We RECOMMEND the use of data transformations (e.g. log metric). It is however necessary to test for normality of the resulting data sets. It is unfortunately likely that these transformations would fail in most of the cases (e.g. for ant and termite data). In that case we RECOMMEND the use of non-parametric statistical methods (assumption-free tests).

Main tests for comparison of means

Question*: Is there significant difference in mean density or biomass between two sites?*

- Parametric test: Student t test.
- Non parametric test: Wilcoxon Mann Whitney.

Question*: Is there significant difference in mean density or biomass between* ***more than*** *two sites?*

- Parametric test: ANOVA.
- Non parametric test: Kruskall Wallis (one-way ANOVA).
- Non parametric test: Friedman (two-way ANOVA).

Suggested software. PC: Statistica ; S+ – Macintosh: Statview

Multivariate analyses

Basic multivariate analyses

***Aims**: Site description, identification of taxa or descriptive data of communities that contribute to site ordination.*

Principal component analysis (PCA)

The database at hand contains two main kinds of data. Mean density and mean biomass of soil fauna taxonomic units. Both of these ***data are quantitative and continuous*** and can be submitted to ***Principal Component Analysis (PCA)***. PCA can also be used to make a classification of the sampled systems according to a package of data including density, biomass and other types of descriptive data of communities (e.g. diversity indices, % of native species, mean vertical distribution, etc).

We RECOMMEND the use of PCA on correlation matrix rather than PCA on covariance matrix when data sets contain information expressed using different metrics (e.g. joint analysis of biomass and pH or biomass and density).

Other analysis

When ***data are quantitative and discontinuous*** (e.g. density data from individual samples), it is pertinent to use a ***Correspondence Analysis (CoA)***.

When data are qualitative (e.g. soil type, land use practices, presence absence data), a ***Multiple Correspondence Analysis (MCA)*** can be performed.

Suggested software.

Either for PC or Macintosh: multivariate analysis and corresponding graphical displays can be performed using a set of software (free of charge) available in the ADE-4 package (Thioulouse et al., 1997).

ADE-4 is available platform at http://pbil.univ-lyon1.fr/ADE-4/ A complete set of user manuals is also freely available (pdf format) at this site.

Guidelines:

- Prepare data set using the module «BinToText» for PCA and COA, and «CategVar» for MCA.
- Perform analysis using the module «PCA», «COA» or «MCA».

Prepare various graphical displays using both «Scatters» and/or «ScatterClass» modules.

Linking taxa and environmental variables

Aims: Comparison of site ordination on the basis of fauna and similar ordination on the basis of environmental variables.

CoInertia Analysis can be used to link results of two multivariate analyses. When crossing e.g. a PCA with faunal data and an other PCA with soil data, the CoInertia analysis give the correlations between taxa and soil parameters. The main significance of the analysis can further be tested with a permutation test.

Suggested software. ADE-4 package (even for analysis and graphics).

Guidelines:

- Perform the two multivariate analyses wanted to be crossed.
- Compare site ordination with the «CoInertia» module (with the options «Matching two statistical triplets» and «CoInertia Analysis»).
- Perform the test with the option «CoInertia test» of the same module.
- Prepare various graphical displays using both «Scatters» modules.

Checking the significance of grouping operated by multivariate analysis

Questions: What are the main driving factors that control macrofaunal communities? At which level do they operate along a scale ranging from local to global levels?

We PROPOSE the ***Between-Within Analysis*** to assess the differences between various subsets of data. For example, we may wish to determine if macrofauna community structure changes according to local, regional of global factors (see the list of factors below). The between-within analysis allows checking for significant differences between groups of data gathered in function of previously identified factors.

List of some factors to be tested according to the scale of observation:

Local scale (comparing different plots within a given site)

- Soil type (e.g. local variations in OM contents).
- Vegetation type (e.g. local variations in vegetation biomass).
- Land-use.
- Slope, topography.

Regional scale (comparing different sites within a given phytogeographic unit)

- Soil type (e.g. Oxisols vs. Ultisols in the Amazon Forest).
- Vegetation type (e.g. savannas vs. gallery forests in a savanna area).
- Land-use.

Continental scale (comparing different phytogeographic units within a given continent)

- Vegetation and soil type (e.g. African savannas vs. African tropical rain forests).
- Climate gradient.
- Altitude gradient.

Global scale (inter-continental comparisons)

- Continents (e.g. African savannas vs. American savannas).
- Climate types (e.g. temperate vs. tropical climates).

The two steps of the analysis:

· **Step 1:**

First we **focus** on the differences between groups of data (i.e. various types of soils, or land-uses, countries etc…)

- Identification of important variables (taxa) that explain sites heterogeneity and groups ordination (i.e. between-classes analysis)
- Ability to test for statistical significance of between groups difference using a non parametrical test (randomisation)

· **Step 2:**

Second we focus on the within groups variability and identify the variable of interest in explaining that variability (i.e. within-classes analysis). This step is done after the between-classes variability has been removed.

Suggested software. ADE-4 package (even for analysis and graphics).

Guidelines:

- Both the between and the within analysis are performed with the «discrimin» module.

References

Thioulouse, J., Chessel, D., Dolédec, S. and Olivier, J. M., 1997, ADE-4: a multivariate analysis and graphical display software., Stat Comput 7:75-83.

Group 5 : Diffusion and communication

Group members :

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The work that was developed by the «diffusion group» was 1) a proposal for the organization of the web page of Macrofauna group, 2) the organization or curricula of different courses and 3) the elaboration of a list of activities to popularize and promote knowledge on soil macrofauna.

1 . ORGANIZATION OF THE WEB PAGE .

We worked on the content and the design of the web page of Macrofauna group. We proposed that the page include the following topics.

1-**Introduction:** this part will contain an explanation of what is the soil Macrofauna, its environmental and economic importance and a brief presentation and history of The Macrofauna Network.

2-**Addresses (Members and Institutions) :** It will include the list of members and the Institutions linked with the **Macrofauna Group or Network,** with their respective addresses. The way to access the participants addresses and names will be by a world map were the countries or regions participating will have different colors. Once the country is selected a window will open with an alphabetical listing of the members and their respective address.

3-**Projects:** Here could be found the information that relates with two kinds of projects: research and applications carried out mainly by NGOS. In each kind of project two parts will be defined: the first will be the projects that are ended (a) and the second the projects that are in process (b).

Information on the projects: name of the project, Institution(s) that financed the project, Institution(s) that carried out the project and listing of the participants. Summary of the results and list of the publications produced during the project.

In the **on going projects** calls could be made for officers or students (PhD), etc. and even offers could be made to develop new project proposals.

of interest:

Activities: An informative page on activities related with soil **Macrofauna**

They will appear organized under the following headings, title of the activity, where it is going to take place, the contact address and any other information of interest:

a. **Meetings**
b. **Congresses**

c. Courses
d. Conferences
e. Research
f. NGO projects

4**. References** It seems adequate to include in the web page the existent data base of the bibliography of Macrofauna, to make the web page an obliged site of reference to any people interested on the subject. It was decided to incorporate the files from the End Note program, because many members of the Macrofauna group work with it and because an important data base already exists in this format.

5**. Websites & Linkages:** This paragraph will be fundamentally information on addresses of other web sites related with soil Marofauna. The list could be an alphebetical listing, but this point still in discussion.

6**. Databases:** One of the most important issue of the web page is the inclusion of the Macrofauna databases. These databases might however be too large to be set in the web page and the responsible Institution or person overloaded. To resolve this problem we suggest that the person responsible for each database opens a web page with its respective data base and thus here the list of databases will be presented with their names, contents, persons in charge and their addresses in the internet to access them directly.

The data base proposed at this moment are:
1. Data Base: **Macrofauna**. Responsible: Dr. Carlos Fragoso.
2. Data Base: **Family Catalogue Glossoscolecidae.** Responsible: Dra. Ana G. Moreno. (with Dr. Carlos Fragoso's and Emmanuel Lapied's collaboration)
3. Data Base: **Taxonomy of Oligoqueta.** Responsible: Emmanuel Lapied.

We hope that other specialists on Macrofauna taxa could make future proposals.
Some other subjects were only pointed out as questions that should be resolved in the future about the maintenance, management and access to these databases (see also report of group 3) . First decide who will be responsible of them, then decide who will have access to modify or introduce more data in the database. Will all the accumulated data be at the disposal of the whole public that consult the web page. Should it be a cost to access the data bases and how to settle it ?

7**. Fauna:** The intention of this part is to provide with simple and interactive identification keys for the soil Macrofauna the public that will access the web page. The suggestion is to start search of the information with a scheme, composed of some boxes with simple figures of animals. These boxes will give access to the information, first a brief introduction to the group and its characters that are used in the identification keys, then the identification Key (the level of identification was not decided) with figures and photos of the animals.

8**. Methodology:** This section contains the whole information on the methodologies used for the Macrofauna studies : animal sampling, soil analysis, treatment and conservation of biological material, design of field or laboratory experiments, data analysis and statistical treatments.

9**. Courses:** We considered that a priority in communication and or divulgation is the elaboration of courses. The curricula should be designed by the members of the macrofauna group and included in the web page. The idea is that the courses are prepared by specialists on the subjects but they could be given by any person from the group or people that consult the web page because the main information will be given in it. The information of the course(s) will be in a Power Point format. The information will indicate the level of the courses and for which public they had been designed, their objectives and the didactic material: figures, drawings and photos with their respective information.

The following levels were considered:

a. University: undergraduate, master and doctorate.
b. High School and secondary and primary school.
c. Local course designed for people that are not related with «official education»: farmers and peasants.
d. Courses for NGOs.
e. Educational games (Black Box and Trapoline (Barois and Aranda and cards with drawings Folgarait, etc.)

10**. Diffusion:** This section includes all the references of the activities that the group had developed and some didactic material like photos, etc…. but always with a diffusing character.

11**. Contact us and Suggestions:** This is an access to the electronic mail of our group where people could contact us, send questions, suggestions or ask for collaborations (see the list of e-mail addresses of all participants of this workshop, at the end of this report).

2. TRAINING COURSES.

We developed some proposals for the courses, games and other activities that would be possible to undertake now.

1. **Courses**. We prepared courses with a diffusing character that can be implemented now ! The information of them is in a Power Point Presentation (Moreno and Paoletti).

2. **Games**. Besides the games of Barois and Arandawhich are played in Mexico, an other game was proposed . A card game: designing cards with drawings and questions to interact (with kids, farmers or peasants) like: who is the larva and who is the adult ? In which place is it found? Who eats it, your neighbour ?

3. **Books**.

An other proposal was to do didactic and easy understanding graphs and figures with the results of our research to give to the farmers and peasants from the sites where we sampled or did experiments.

3. POSSIBILITIES TO DO INFORMATION.

In this theme only some possibilities were pointed out, we note some below, but we did not prepare any strategy to follow up.

1. **Production of documentary videos :**

a) First proposal is to do a video of what is the soil macrofauna, what is the Macrofauna group and which are our activities.

b) An other possibility is to contact people that work in the nature documentary production, and ask them to do a documentary on soil Macrofauna (David Attenborough, National Geographic, Canal +, IMAX, WWF International, BBC World, Discovery Channel, etc..

c) An other possibility is to make a listing of all the documentaries that are available on this subject and may be build up a videotheque:

- Indians in Colombia and Venezuela eating EW (German,...).
- Grunting Extraction (vibration) in sandy soils in Florida USA (Paul Hendrix Uni. of Georgia)
- Soil biota in temperate forest (Andrew Moldenke, Uni. Oregon)
- Life in soil (Japanese Publication).
- Earthworm biology (Otto Graff, Germany).
- Archimède n°7 « La terre vue par la Science » (56 mn VHS SECAM. SESAME Films. 8, rue Gambey, 75011 Paris)
- Termites attack (collection les envahisseurs invisibles) Réalisateur : Thierry Bernard, Conseil scientifique : Corinne Rouland/Alain Brauman, Coproduction : IRD (ex. ORSTOM), Mona Lisa Production, TVFrance 2.

2. **Publication of articles in vulgarisation journals:** Scientific American, La Recherche, etc. The members of the Macrofauna Group should write the articles and they will treat basic and concrete subject of each specialist.

3. **Internetting:** the suggestion is to send some information of our activities and group in networks that are in the internet, like Jacky Foo for Sustainable Agriculture, etc..

4. **Organization of a travelling exhibition on soil Macrofauna for Natural History and Science Museums**, etc. : Basically it will consist of 2 questions that will be answered by the exhibition:

What is the soil? What is the Macrofauna? Where is the macrofauna? Is it in extinction danger ? Which relationships do it has with the humankind? Why do we have to conserve and protect the soil Macrofauna?