MINISTRY OF THE ENVIRONMENT

EVALUATION OF THE STATE OF KNOWLEDGE ON BIOLOGICAL DIVERSITY IN BRAZIL

Executive Summary

Biodiversidade 7

EVALUATION OF THE STATE OF KNOWLEDGE ON BIOLOGICAL DIVERSITY IN BRAZIL

Executive Summary

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NATIONAL BIOLOGICAL DIVERSITY STRATEGY PROJECT

EVALUATION OF THE STATE OF KNOWLEDGE ON BIOLOGICAL DIVERSITY IN BRAZIL

Executive Summary

Brasília
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Evaluation of the State of Knowledge on Biological Diversity in Brazil: Executive Summary

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Preface

As the country with the world's greatest biological diversity, ranging from 15% to 20% of the Earth's described species, Brazil has a deep responsibility towards the Convention on Biological Diversity, especially with respect to species conservation and sustainable use. In order to be successful on conserving and responsibly utilizing this rich patrimony, it is crucial that we understand our species and their occurrence on this vast territory.

Having this in mind, our first task was to evaluate its current state. This extensive task, here presented as a summary, was made possible through a collaborative work between the Ministry of the Environment –as part of the development of the National Biological Diversity Strategy– and respectable researchers, who compiled this information scattered in institutions, museums, and scientific collections. This work compilation both identified the major gaps in Brazil's biodiversity knowledge– related to taxon, region and biome whenever possible–, and emphasized our urgent need on being familiar with this immense legacy.

The knowledge of our biodiversity is the foundation on which responsible public policies on its conservation and sustainable use can be developed. This knowledge is pressing considering the threats of the explosive and disordered populational growth, the social and economic disparities and, above all the environmental degradation –such as natural resources over exploration, invasive exotic species introduction, and habitat fragmentation and loss– on this precious diversity of species.

This document represents a priceless mark on Brazilian biological diversity knowledge that the Ministry of the Environment proudly provides to the Brazilian people in general, decision-makers, researchers and institutions, non-governmental organizations, and all our partners in biodiversity conservation and sustainable use. Among our next steps and challenges are the expansion of this knowledge base and the responsible, fair and integrated management of this valuable biological diversity.

I am very grateful to the specialists who put a lot of effort compiling and producing this special information as well as the others who provided information to the specialists' compilation. I also compliment those who contributed to this summary's production in different manners.

Marina Silva

Minister of the Environment

Presentation

The Conference on Environment and Development – Rio-92, held in Rio de Janeiro in 1992, drew the attention for the need of the world's environmental conservation through the Convention on Biological Diversity –CBD, which was signed by 170 countries– being Brazil its first signatory.

After signing the CBD, Brazil pledged to promote the conservation of biological diversity on its territory as well as the sustainable use of its components and the equitable sharing of the benefits resulting from the use of genetic resources. In order to implement the terms agreed by the CBD, in 1998, the Ministry of the Environment (MMA) created the National Biological Diversity Strategy Project. This aims to provide necessary information to the Brazilian government and society on establishment of priorities for national biodiversity conservation, sustainable use and benefit sharing through strategies, plans and programs. This Project is funded by the Global Environment Facility, and supported by the United Nations for the Development Program (UNDP), the Brazilian Agency of Cooperation (ABC), and the Brazilian Council of Research (CNPq).

Although Brazil is the richest country in the world in terms of biological diversity, the extent of this resource is vastly unknown. Additionally, information on its biodiversity has been dispersed in institutions, museums, and scientific collections. In order to compile such information, the National Biological Diversity Strategy Project and a group of researchers promoted the *Evaluation of the State of Knowledge on Biological Diversity in Brazil*, here presented as a brief profile. This publication contains data on biological diversity of Brazilian microorganisms, marine invertebrates, terrestrial invertebrates, freshwater organisms, vertebrates, terrestrial plants, and genetics. Our intention and challenge were first to be familiar with such biodiversity to then be able to conserve and sustainably use it through responsible and serious public policies. Among the general actions recommended by the specialists to fulfill the gaps found in the Brazilian biodiversity knowledge are: (1) the improvement of collections and museums; (2) the training and employment of researches and technicians; (3) the encouragement of taxonomic revisions and publications; and (4) the production of identification guides.

The results presented in this publication provide to the Ministry of Environment the scientific basis necessary to guide MMA's strategies and action plans for a successful conservation and sustainable use of such valuable resources.

João Paulo Capobianco
Secretary for Biodiversity and Forests

Contents

Introduction

The project whose results we present here in summarized form came to be at a unique occasion in Brazilian ecological science. After the Rio-92 World Environment Conference, a few scientists self-convened in several informal meetings to discuss a particular problem -the lack of compiled information on the current knowledge of Brazilian biodiversity. By hosting the conference and being the first country to sign the Convention on Biological Diversity, the Brazilian government had assumed a number of obligations that entailed urgent legislative and executive actions. From the standpoint of the scientific community, the government would need expert assistance on Brazilian biological diversity to accomplish these tasks; but, though we recognized that substantial knowledge and expertise indeed existed, they were neither readily accessible nor understandable, being scattered in academic publications, unpublished theses or quite often confined to scientists´ personal unwritten knowledge. In brainstorming for various ways of making published and expert knowledge effectively available, among other fruitful ideas the present assessment was conceived and outlined.

Those early meetings of the GTB (Biodiversity Working Group, recognized in 1997 as an advisory board by the President of the CNPq, the Brazilian National Research Council) took place by invitation of Dr. Bráulio Ferreira Dias, then the Director for Biodiversity Conservation of the Ministry of the Environment, who challenged us to formalize this idea as a proposal. After about two years, this proposal was commissioned by the Ministry to be incorporated into the UNDP and GEF-supported project for a National Biological Diversity Strategy.

These beginnings of the project seem worth recounting not only for historical interest, but for what they reveal on an evolving relationship between biological scientists and government. Many Brazilian biologists until quite recently have seen themselves, by choice or fate, removed from whatever implications their work might have on governmental decisions for Science and Technology and their applications, but this does seem to be changing. Scientists who work in various ways on biological diversity generated this proposal to meet what they recognized as an institutional need. Though this was neither the only nor the first resource assessment to be undertaken by the biological academic community in Brazil, it did happen at a moment where some government agencies were particularly receptive. It also proposed to assess conditions for producing and organizing knowledge on biodiversity in a different way, aiming at other uses for this knowledge beyond its worth as basic research.

We expect this receptiveness to signal a continued two-way interaction between scientists and governmental institutions in charge of biodiversity policy and actions. Today, most Brazilian biologists have a clearer view of the social and institutional dimensions of their work. This is not to say that freely chosen, curiosity-driven research is being diminished in any way –it is and always will be the matrix from which genuine scientific novelty can emerge. But, concerning biological diversity, a large community of scientists, engaged in field collecting and taxonomic studies, nowadays perceive that their work reaches far beyond the immediate knowledge of their chosen group. Many of these scientists share a sense of urgency, both in advancing our total knowledge of Brazilian biodiversity and in making this knowledge immediately usable, and thus somehow to influence the future prospects of conservation and the sensible use of this very biodiversity.

In planning this assessment, we had to make some decisions from the outset. A complete and precise survey of people, institutions and extant knowledge would be almost impossible to achieve, and setting this kind of goal might delay its completion forever. We proposed instead a

different criterion, striving for usefulness rather than perfection. This we hope to have achieved to some degree. Though the picture we present is rough at the edges, we are confident that it is fairly comprehensive and correct in the essentials.

The picture that one sees in this assessment may emerge as quite singular, though not unique, in world terms. Brazil is unanimously ranked among the leading holders of the world's biodiversity. Among the so-called megadiverse countries, unfortunately many do not have an adequate resource base, human and institutional, for its study. Brazil is one of the exceptions: a country with a rich and varied biodiversity, allied to a significant research capacity. Though the country sorely needs more researchers, and more and better facilities, our first, if not foremost, priorities are putting the extant knowledge to use and engaging available researchers through adequate and steady employment. These go hand-in-hand with the evident necessity for urgent and well-planned surveys in less-known biomes; for stimulating the training of researchers devoted to poorly-known but important habitats and taxonomic groups; for fostering new or existing institutions and groups in less-endowed regions to work at a high standard; for attracting more geneticists to research the genetics of natural populations including, but not restricted to, endangered species; for the dissemination of biodiversity knowledge in diverse formats and media, to stimulate interest and use by non-specialists.

Brazil has very real possibilities for all of these, but cannot do so alone. International academic cooperation and exchange have always been, and more than ever are, a critical precondition for advancing the knowledge of biological diversity, and this for two very simple reasons: first, species and populations transcend political borders; second, taxonomic and ecological specialists are far too few, scattered the world over, and uncorrelated with their own countries´ biodiversity. Putting its own resources to good use, creating opportunities and support channels for novel undertakings in biodiversity research, and promoting the effective and equitable joint production of new knowledge – these are the three major challenges that we hope Brazil will rise to meet.

Thomas M. Lewinsohn

Biodiversity of Brazil:

A Synthesis of the Current State of Knowledge

Mosaic plant *Ludwigia sedoides*
Photo: Magno Botelho Castelo Branco

Rooted waterhyacinth *Eichhornia azurea*
Photo: Magno Botelho Castelo Branco

Golden-backed squirrel monkey *Saimiri ustus*
Photo: José Sabino / Natureza em Foco

Jellyfish *Ectopleura obypa*
Photo: Alvaro Migotto

Biodiversity of Brazil: A Synthesis of the Current State of Knowledge

Thomas Michael Lewinsohn[1] & Paulo Inácio Prado[2]

History

This project was conceived in 1997 in the Biodiversity Working Group, an independent advisory board attached to CNPq, the Brazilian National Research Council. It was initially motivated by the lack of organized information on the existing knowledge of Brazilian biological diversity, as attested for instance by the scarce information on Brazil found in the World Conservation Monitoring Centre's "Global Biodiversity", the chief global survey prepared for the Rio-92 Conference. The project was contracted at the end of 1997 by the Section of Biodiversity and Forests (then the General Bureau of Biodiversity) of the Ministry of the Environment of Brazil, with GEF/UNDP funding, as part of the development of the Brazilian National Biodiversity Strategy. The data for the project were mostly collected from the end of 1997 to early 1999 and were organized and analyzed in 1999 and 2000.

The central objective of the project was to produce a profile of the current capacity and knowledge on Brazilian biodiversity and therefore to assist the choice of priorities for the further development of this knowledge and its application, thus fulfilling the international obligations assumed by Brazil under the Convention on Biological Diversity and, internally, under the Federal Constitution and the specific laws on the environment.

Data from initial versions were incorporated in the First Brazilian Report for the Convention on Biological Diversity (1998). Final versions of specific reports were presented by early 2000. At the end of 2002, the final synthesis was published (T.M. Lewinsohn and P.I. Prado, "Biodiversidade brasileira: síntese do estado atual do conhecimento", Editora Contexto, São Paulo). This is a partly updated and expanded version of the Summary of the text published in 2002.

Strategy, Methods and Data Sources

The work was carried out with a group of consultants, whose tasks were allocated by a combination of taxonomical and/or environmental categories, in order to profit from familiarity and ease of contact among specialists working on similar groups and habitats. This subdivision resulted in seven detailed reports (see Table 1). These are summarized separately after this text.

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[2] Núcleo de Estudos e Pesquisas Ambientais, Universidade Estadual de Campinas, Campinas, SP.

Table 1. Main project topics and respective main consultants.

Topic	Consultants
Microbial diversity	Gilson Paulo Manfio
Marine invertebrates	Alvaro Esteves Migotto and Antonio Carlos Marques
Terrestrial invertebrates	Carlos Roberto F. Brandão, Eliana Marques Cancello and Christiane Izumi Yamamoto
Freshwater invertebrates and plants	Odete Rocha
Vertebrates	José Sabino and Paulo Inácio Prado
Terrestrial vascular plants	George John Shepherd
Genetic diversity	Louis Bernard Klaczko

The key information source was a questionnaire, distributed by the main project consultants and their collaborators to specialists on various taxonomic groups and areas of knowledge and from different institutions. The purpose of the questionnaire was to obtain information on: the current status of the taxonomy of each group; the state of knowledge of its diversity in Brazil and the world; extent of sampling in different biomes, habitats or geographic regions of the country; the value of each group for different applications and lines of interest; genetic studies of or within the group; current human resources; state and extent of biological collections; and needs and proposed priorities to advance knowledge of the group. The questionnaire was structured to elicit evaluations by specialists based on their experience; most questions offered choices on a reduced scale of qualitative or, whenever possible, ordinal alternative answers.

Although it would be desirable to get responses from the maximum number of specialists, the chosen goal was to obtain a full set of answers from at least one active specialist in each main group. In all, more than 400 specialists were contacted; questionnaires were returned (with full or partial answers) by 148 and 27 more provided supplementary information on vertebrates. The rate of returned answers is comparable to that of other similar studies. The taxonomic entities on which each specialist provided information varied from phylum (most common in marine invertebrates) to family (especially within terrestrial arthropods), according to the usual level of specialization within each group.

Other sources examined for additional information included databases and various directories on the Internet (especially the CNPq research group databases and directories of taxonomic specialists), several bibliographic databases on CD-ROMs or the Internet (Biological Abstracts, Zoological Records, Aquatic Science and Fisheries Abstracts, etc.), and various technical reports, workshop proceedings and other publications.

Total Estimates of Brazilian Biodiversity

There are, at present, no sufficiently comprehensive compilations to count the number of species recorded in Brazil. Nonetheless, we produced for the first time an estimate combining information obtained from specialists and the literature with inferences based on the known percentage of Brazilian species versus world totals in some better-known groups or on intragroup

proportions. We estimate that till now roughly 200,000 species (within an interval of 180 to 225 thousand) have been recorded in Brazil, most of them in large taxa whose species listings are still quite incomplete or nonexistent.

The diversity of better-known taxa in the country indicates that Brazilian species correspond to circa 14% of the world's biota. Applying this ratio to the estimated global number of species in major taxa, we estimate the total species diversity of Brazil on the order of 2 million species. This figure has to be understood as a first approximation given the significant gaps in our knowledge, but it leads us to expect Brazilian biodiversity to be about ten times larger than what is currently known. Even with conservative estimates the expected total species diversity in Brazil is six times the currently recorded number.

Taxonomic Expertise, Institutions and Facilities

The responses of specialists to our survey show that, though Brazil has a substantial and well-established set of institutions and human resources, to attain a reasonable level of knowledge of the country's biodiversity it would require a substantial additional effort, larger than all the work done heretofore. If the number of unknown species is indeed 10 times the currently known ones, at the present rate of study it would take several centuries to attain adequate coverage of all groups. To complicate matters further, in most taxa clearly the undescribed species are smaller, less conspicuous and harder to collect or sample than the ones already known.

According to specialists, in many taxa the Brazilian or Neotropical genera, and sometimes families, are not well established and in need of revision. In most taxa, species can only be identified or sorted reliably by specialists, with the help of reference collections. However, Brazilian biological collections were deemed sufficient for study of only about 25% of taxa, and considered totally inadequate for 27% of them. Even major collections have a critical deficit of curators in their permanent staff.

Scientific libraries were considered satisfactory to work on 47% of the evaluated taxa, and totally inadequate for 7%. A particular gap in the scientific literature is the lack of identification guides and keys; none of these is seemingly available for 35% of the taxa on which information was obtained. Moreover, a substantial part (38%) of studies deemed important by specialists is only published as theses or reports that are hard to obtain. Nonetheless, answers to our survey indicate that for most taxa there are Brazilian researchers capable of producing identification guides which could mostly be completed within four to six years.

Most important collections and libraries are concentrated in few institutions, chiefly located in the Brazilian Southeast. Almost 80% of the better collections, according to specialists, are located in the Southeast and South. Half of the most important collections referred to by specialists are harbored in only seven institutions; four of these are in the Southeast, one in the South and two in the North. Larger research institutes and universities accommodate several collections of animal and plant taxa, but the outstanding microbial collections tend to be harbored in a distinct set of institutions.

The number of specialists in activity was judged insufficient for the vast majority of taxa, and there are several important groups, especially within the invertebrates, where not a single active specialist could be located in Brazil; only for 5% of the evaluated taxa did the consulted specialists believe that there are enough researchers in the country. Similarly to collections and libraries, specialists are massively concentrated (ca. 80%) in the South and Southeast (see Figure 1).

We estimate that the number of taxonomists in Brazil has to be at least tripled. This estimate is based on the number of currently active specialists and the additional number of needed specialists in several taxonomical groups. Survey responses indicate that this is feasible by training new taxonomists and employing available professionals. According to our respondents this can be accomplished in the short term and by professionals in Brazil, given the necessary material conditions.

The survey of researchers on genetic diversity was conducted with a separate questionnaire. Research groups and publications were sorted according to the main techniques employed to assay genetic variability. A sizable number of research groups were located, even though several are employing less effective or partly obsolete methods. This, however, is a minor problem. The key difficulty is that few researchers are directly concerned with investigating genetic diversity in natural populations. For example, no study of genetic variability in felines could be found, even though this is a group of high conservation concern. To further our knowledge of genetic diversity, the main priority would thus seem to be to motivate and attract research groups to turn towards questions and taxa most relevant to the understanding of biological diversity.

Expert Opinion on Needs and Priorities

Priorities most frequently chosen in all groups to enhance knowledge were, firstly, the improvement of collections (by either studying and organizing existing holdings or expanding them through planned collecting) and, secondly, by increasing technical support staff. Employment of researchers was most commonly indicated as a priority for terrestrial invertebrates and vertebrates, whereas capacity building through taxonomist training was most often indicated for marine invertebrates.

Virtually all taxa included in survey responses were considered as a priority for biodiversity studies by their specialists, who asserted either the need of further understanding of the diversity and biogeography of the group in Brazil or its ecological and economic importance. Most taxa mentioned in survey responses (85%) were also considered of high priority for systematic studies. Survey responses indicate that the main goal of systematic studies still is the inventory and description of species that occur in Brazil, and so emphasize how limited our current knowledge of Brazilian biodiversity still is. In evaluating the importance of different taxa, the majority (83% of those informed) was seen as relevant for basic research, although most specific choices picked by responses were of applied nature.

Geographic and Ecological Coverage

Sampling extent in most Brazilian biomes was considered inadequate for all taxa, except for vascular plants. Relatively speaking, the Atlantic Forest is the best studied biome and it is judged to be reasonably to fairly well sampled for most vascular plant, vertebrate and terrestrial invertebrate taxa. The Amazon Forest, Cerrado, Southern Plains and Mixed Forests, as well as the Coastal Ecosystems received intermediate ratings by experts as to their sampling coverage, some taxa being fairly extensively collected and studied. At the other extreme we find the Caatinga and the Pantanal, biomes that are judged to be poorly sampled and badly known for the great majority of the evaluated taxa.

A literature survey of the last 15 years of the 20th Century showed that species inventories in Brazil are very concentrated on a few taxa and not necessarily those least known. Again, 60% of the inventories are within the Southeast and South, and half of the studies in natural systems concentrated on the Atlantic Forest or Amazon biomes (see Figure 1). A remarkably high proportion of all inventories, circa 1/3 of all published studies, were carried out in ecosystems modified by human action and most of these focused on taxa of medical or agricultural interest.

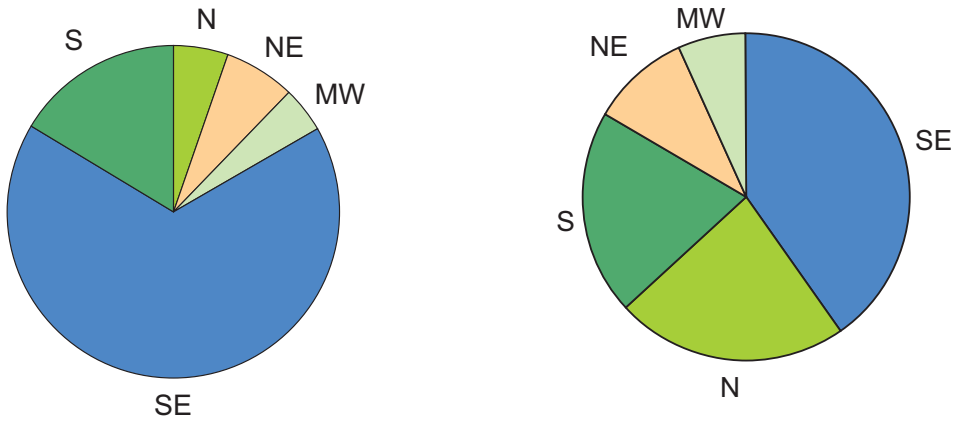


Figure 1. Left: Proportional distribution of cited taxonomic specialists among geographic regions of Brazil, based on questionnaires returned by informers. Biological collections (not shown) have a very similar distribution. More than 80% of cited specialists are from institutions in the Southeast (SE) or South (S). Right: Published inventories cited in the Zoological Record 1985-1999, authored or co-authored by researchers with Brazilian professional addresses, by geographical region. Though the imbalance is smaller than for researchers and institutions, the Southeast and South together still account for 60% of the total. Many taxonomists and field biologists do not work only within the geographic region where they are professionally based. For example, 23% of the studies concern the Amazon (N, Northern region) but their authors do not solely reside in that region. By any criterion, the Northeast (NE) and Mid-West (MW) are the most disadvantaged regions in terms of researchers and scientific study.

Conclusions and Recommendations

Taken as a whole, our results show a still very inadequate, and also quite uneven, general level of knowledge of biodiversity in Brazil, as well as of the resources to further this knowledge. Given this picture and the urgent need of information on biodiversity, goals for future investigation and capacity building have to be set with a comprehensive strategy and a clear understanding of the intended use of this information. Clearly, spontaneous research without any special support or direction cannot possibly cope with even the most pressing needs for knowledge on biodiversity.

Given this dilemma, we suggest several actions, whose priorities and particulars have to be fit to the current state and potential of each taxonomic group and ecogeographic region. We propose that policy should be initially split into two major channels, for each of which we indicate some examples:

♦ Use of existing knowledge and capacity:

- Detailed study of available collections, prioritizing well-represented groups with solid taxonomy; quick electronic publication of comprehensive catalogs and checklists;
- Encouraging the production and publication of taxonomic revisions and identification guides, especially those accessible to non-specialist technicians, teachers, etc.; these have to be given equal weight to scientific publications and not be treated as byproducts or personal hobbies of scientists, in evaluating their productivity;

- Consolidation of material and technical infrastructure of collections, especially through the establishment of permanent positions for curators, technicians and support staff. Such positions may be demanded from institutions as counterparts to research funding from outside sources.

♦ New initiatives:

- Establishing and strengthening regional centers, especially in the Northeast and Mid-West regions, including them in national or regional projects for biodiversity inventory or monitoring in collaboration with experienced groups;
- New inventories in little-known regions and habitats with georeferencing and common sampling designs and procedures that allow comparative and quantitative analyses;
- Deployment of new bioinformatic technologies to speed up the cataloging and diffusion of biodiversity knowledge and to facilitate its access and use;
- Joining international initiatives, especially those that foster partnerships with institutions holding strong collections and researchers experienced in Neotropical biota.

Since the main data survey and analysis for this project were completed in 1999 and 2000, a number of promising trends are apparent. Although no systematic update has been conducted, we recognize for instance:

- A clear increase in published field studies, inventories and surveys based on sound sampling designs and using appropriate statistical methods, together with publications and courses that offer guidance on such field methods and analyses;
- A growing number of taxonomic revisions and synopses;
- A noticeable increase in published field guides, mostly to vertebrate groups or flowering plants, but also to some invertebrate groups, which are accessible to non-specialists and in many cases to nonscientists as well.
- Some new research groups are striving to become established in the regions shown to be in need of more institutions and researchers.

Such trends are certainly encouraging and raise expectations that usable and applicable knowledge on Brazilian biodiversity can be substantially improved even in the short term. However, these favorable signs are still offset by the obstacles that were recognized in the initial survey. An increasing number of well-trained researchers graduated in Brazil or abroad are wasting their capacity due to lack of adequate jobs. At the same time, many biological collections and databases are going to waste for want of minimum competent staff. This combination results in a net loss of precious resources.

Given that biodiversity research work, including assessment and monitoring, are intrinsically labor-intensive, researchers and technicians must not only be adequately trained but steadily employed in order to ensure the capacity of producing and processing extensive samples in relatively short time. These tasks can be speeded up by several means, some of which were mentioned above, but they cannot ever obviate the need of well-trained and sizeable research groups both for field and laboratory work.

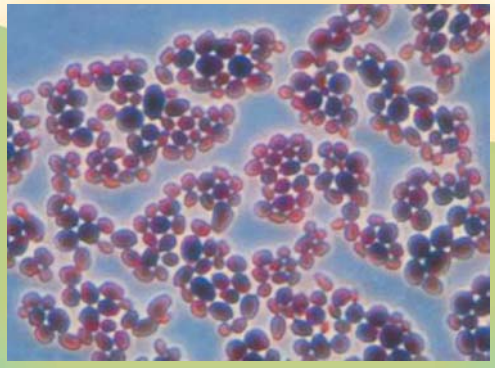
Another current concern regards the difficulty in controlling specimen sampling and/or the export for illegal gain - biopiracy - without, at the same time, hampering legitimate research, which is not only desirable but urgently required. Two key issues are restrictions on field work by Brazilian researchers, and specimen loans to and from collections in foreign institutions. Whereas researchers recognize and support efforts to control malicious sampling of biological specimens, legitimate

research has to be recognized and adequately shielded from similar treatment. International exchange with *bona fide* research institutions, within the country as well as overseas, likewise is a major asset towards improvement of biodiversity knowledge. Yet another related issue is the quite strict procedures for research in Brazilian protected areas. Again, while these are undoubtedly necessary, current requirements are often cumbersome, ambiguous and slow to fulfill. Ensuing delays ultimately act against the urgent need for more and better information to improve assessment and management of biodiversity within these very same protected areas.

Government agencies and the scientific community in collaboration should develop streamlined policies and procedures to provide appropriate safeguards, as well as to enhance –rather than to obstruct– Brazilian researchers in their work, including overseas collaboration. Improvement in these matters will probably provoke an immediate net gain in the extent, quality and usefulness of scientific information on Brazilian biodiversity.

Microorganisms

Photos: Patrícia Mariana Zachello



Yeast *Saccharomyces cerevisiae*

Bacteria *Alicyclobacillus* sp.

Microorganisms

Gilson Paulo Manfio[1]

Introduction

An extensive survey on the state-of-the-art of microbial diversity in Brazil, focusing both on microbial taxa and researchers, was part of a biological diversity inventory coordinated by Dr. Thomas M. Lewinsohn in the National Biological Diversity Strategy Project ("Estratégia Nacional de Diversidade Biológica" - BRA97G31-MMA/GEF/PNUD) of the National Biological Diversity Programme ("Programa Nacional de Diversidade Biológica" - PRONABIO)[2].

The conclusions and synthesis of the national inventory were published in 2003 by Lewinsohn and Prado. In this Executive Summary we present the main results of the Microbiological Survey of this study. Extended data from the survey can be found in the publications site of the Directorate for Biodiversity Conservation (DCBio), Ministry of the Environment (*Avaliação do Estado Atual do Conhecimento Sobre a Diversidade Microbiana no Brasil: Relatório Final – Revisado;* http://www.mma.gov.br/port/sbf/chm/doc/microb1.pdf).

Microbial Diversity

Microorganism is a taxonomic definition that encompasses diverse groups of unicellular organisms of microscopic dimensions that live in nature isolated or in cell aggregates. These include the bacteria, archaea, filamentous fungi and yeasts, protozoa and viruses.

Microorganisms were the first life forms that colonized Earth. It is estimated that microbial life began more than 3.5 million years ago. Today, it occurs in virtually all habitats on the planet, thriving under environmental conditions that surpass tolerance levels of most plants and animals, including geothermal sources, deserts, polar habitats, alkaline lakes, subsurface sediments and even inside rocks.

The existence and diversity of all life on the planet is intimately linked to the diversity and metabolic activity of microorganisms in nature. Microorganisms play important roles in ecological processes, such as photosynthesis and the generation of oxygen, organic matter cycling, biogeochemical cycles (carbon, nitrogen) and the maintenance of soil fertility and structure, among others.

Despite their enormous ecological importance, the number of known microbial species (species diversity), represented by cultivated organisms described in the literature, represents a small fraction

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of the microbial diversity found in nature (between <0.1 to 1%, depending on the habitat), estimated from studies based upon direct analysis using molecular methods.

The modern phylogenetic classification of microorganisms, derived from analyses of ribosomal ribonucleic acid (rRNA) sequence data, places the different microbial groups into three major Domains: *Bacteria, Archaea* (archaebacteria) and *Eucarya* (includes the fungi and protozoa).

Each of these has their own classification and identification schemes, follows different biological nomenclature codes and is the focus of attention of independent and separate research communities, comprised by bacteriologists (including specialists in archaea), botanists[3], mycologists, protozoologists and virologists.

It is estimated that, on a global scale, the diversity of microorganisms exceeds, by some orders of magnitude, the diversity of plants and animals. Surveys from the 1990s state that only 5% of the fungi are currently known, with approximately 69,000 described species. For prokaryotes, including bacteria and archaea, 4,314 species are known, allocated into 849 genera, corresponding between 0.1 to 12% of the diversity estimates for the group. Protozoa and viruses have about 30,800 and 5,000 described species, respectively, corresponding to 31% and 4% of the estimated number of species.

In many cases, characterization of species in some microbial groups is poor, due, partly, to difficulties in growing the organisms in the laboratory and performing routine characterization tests. These deficiencies make the identification of environmental isolates a hard and subjective task. In consequence, many diversity surveys rely on the adoption of low-resolution taxonomic schemes, where isolates are frequently assigned to high rank taxonomic groups, such as genera, families or above, or even based on the assignment to major functional groups (diverse organisms that perform common functions in the environment, such as the cellulose-degrading microorganisms, including bacteria and fungi).

The considerable dimensions of microbial diversity make it very difficult to conduct a comprehensive survey on the state-of-the-art at the national level, turning the effort into a very complex task. The strategy for gathering information on research professionals in areas related to the theme involved two distinct and complementary approaches:

1) surveying data on professionals and institutional/departmental/personal lines of research by accessing Brazilian public-domain *Curriculum Vitae* information systems and databases of publications from the last ten years (1989-1996), and;

2) distributing a standard questionnaire to obtain data from professionals identified as “research group leaders” and individual researchers holding M.Sc. or higher degrees in the areas of bacteriology, mycology, food, industrial, medical and soil microbiology, fermentation processes, molecular and microbial genetics, and virology.

Databases consulted included:

- Who-is-who in Biodiversity (“Quem é Quem em Biodiversidade”)[4].
- the “Cadastro Nacional de Competência em Ciência e Tecnologia”, from the CNCT (http://reaact.cesar.org.br/cnct/novo-cnct/htmlEstatico/Welcome.html).
- the directory of research groups in Brazil (“Diretório dos Grupos de Pesquisa no Brasil”), from CNPq, versions 2 (http://www.cnpq.br/gpesq2/) and 4 (http://www.cnpq.br/gpesq3/dgp4).

[3] The taxonomy of photosynthetic bacteria, known as blue-green algae, or Cyanophiceae, is also independently worked out by botanists and ruled by the Botanical Code, following classification schemes different from the Bacteriological Code.

[4] The Ministry of the Environment now coordinates the Biodiversity Information Network (“Rede de Informações em Biodiversidade” - BinBr; http://www.binbr.org.br/quem), and the database Who-is-who in Biodiversity (“Quem é Quem em Biodiversidade”), formerly hosted at Fundação André Tosello (http://www.bdt.org.br/bdt/whobio - now inactive).

- the Lattes *Curriculum Vitae* database ("Base de Currículos Lattes", from CNPq, version of March 2003 (http://lattes.cnpq.br/).

Despite the lack of a unified database on researchers and research activities at the time of the first survey[5] and some limitations of some of the sources (outdated records, different classification schemes for research areas and activities), and the poor response to the printed questionnaires, compilation of the data obtained allowed us to evaluate the overall state-of-the-art of microbial diversity at the national level.

Results and general trends observed in relation to the geographical distribution of professionals and research lines evaluated at the end of 1996 (first survey) were corroborated by supplemental surveys conducted on data from the Lattes CV Database, performed in March 2003[6].

The geographical distribution of researchers in Microbiology (Table 1) is discontinuous in Brazil, and directly related to the number of research institutions in the different geopolitical regions of the country. The vast majority of professionals are located in institutions in states of the Southeast (Minas Gerais, São Paulo and Rio de Janeiro) and South (Paraná, Santa Catarina and Rio Grande do Sul) regions.

Several factors may have contributed to this, including historical and institutional aspects, infrastructure and resources for funding research. However, it is worth noting that the North, Northeast and Mid-West regions encompass areas of considerable global biodiversity, including the Amazon tropical rainforest, Cerrado (savannah), Pantanal (wetlands) and remaining portions of the Atlantic Forest. The shortage of professionals working in institutions located near or in the heart of these assets certainly represents a significant limitation to the knowledge on the microbial diversity in such Brazilian areas of high biodiversity.

Table 1. Geographical distribution of professionals and institutions related to microbial diversity research in Brazil (data from 1996).

Regions	Institutions	Professionals
North/Northeast	4	5
Mid-West	4	9
Southeast	22	62
South	6	15
Total	**36**	**91**

Results from a supplemental survey conducted in March 2003 (Table 2) using the Lattes database (http://lattes.cnpq.br), did not reveal a large increment, compared to data from 1996, in the number of researchers assigned to the category "Microbiology", listed both under the Biology (coded 2120) and Agriculture (coded 5010) science directories. Again, most professionals figured in institutions from the Southeastern (59%) and Southern (17%) regions (Figure 1).

[5] The "Base de Currículos Lattes" of CNPq/MCT represents a unified national information system, holding more than 8 million entries (March/2003) on researchers from different scientific and technological areas.

[6] For more information see http://www.mma.gov.br/port/sbf/chm/doc/microb1.pdf.

Table 2. Number of researchers classified within areas of Microbiology (coded 2120) and Agricultural Sciences (coded 5010) in the Lattes database (CNPq/MCT, 19 March 2003).

Classification CNPq	Areas	Total *per* main area[a]	%	Total with redundancy[b]	%
21200009	Microbiology	394	18.0	1,018	18.4
21201005	Biology and Physiology of Microorganisms	109	5.0	443	8.0
21201013	Virology	176	8.0	327	5.9
21201021	Bacteriology	250	11.4	536	9.7
21201030	Mycology	160	7.3	354	6.4
21202001	Applied Microbiology	226	10.3	826	15.0
21202010	Medical Microbiology	366	16.7	753	13.6
21202028	Industrial and Fermentation Microbiology	229	10.5	594	10.8
50101048	Soil Microbiology and Biochemistry	242	11.1	468	8.5
50102044	Agricultural Microbiology	37	1.7	205	3.7
	TOTAL	**2,189**		**5,524**	

[a] Professionals that selected the specific area as their major field in the database system.
[b] Professionals that selected the area as one of their research fields.

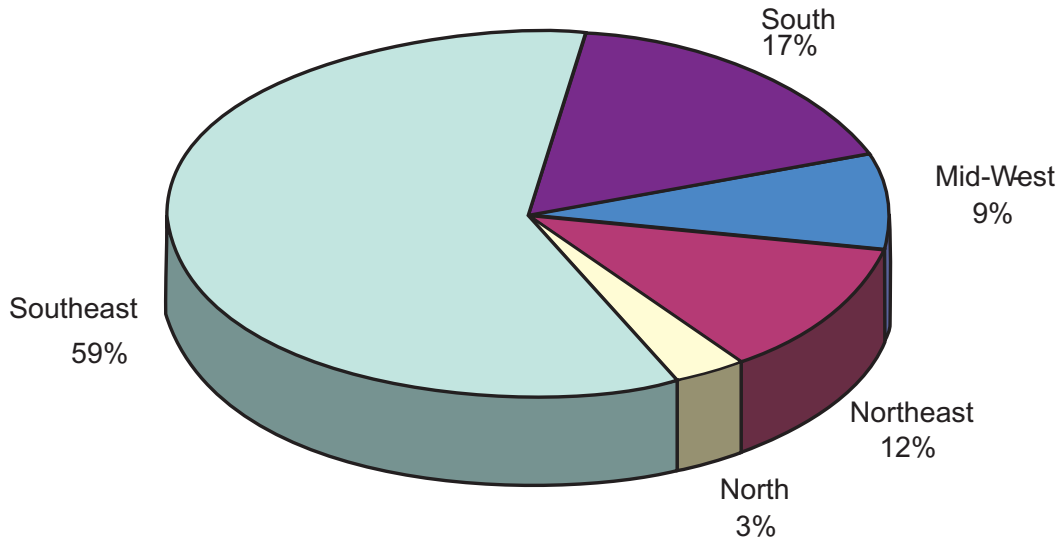


Figure 1. Geographical distribution of institutions from professionals classified in the main areas Microbiology (code 2120) and Agriculture (code 5010) in the Lattes database (CNPq/MCT, 19 March 2003).

A detailed analysis of research lines and publications from the different groups identified in this survey indicated that, as a whole, research in microbial diversity, and, consequently, the specific knowledge on the extent of the diversity of microorganisms in Brazil, is limited to a small number of researchers and to a relatively narrow range of taxonomic groups, with heterogeneous geographical coverage.

Research projects are mainly focused on taxonomic characterization and identification of specific microbial groups, using classical (phenotypical) methods based on growing the organisms and observation of morphological features, metabolism and physiology. The use of molecular characterization and culture-independent methods, aimed at the study of complex microbial communities in the environment and at characterizing the infraspecific genetic diversity, was identified in six research groups, some still striving to consolidate themselves in the field.

Taxonomic diversity of genera and species of microorganisms in Brazil is better known and documented for the filamentous fungi. There are rich and diversified literature sources, including taxonomic revisions and species inventories conducted in Brazilian biomes. However, these tend to be concentrated in a reduced range of taxa.

Diversity of archaea, bacteria, yeasts, protozoa and viruses, mainly for groups isolated from the environment, is still poorly known. Literature on these groups in Brazil is mainly focused on, and somewhat restricted to, clinical microorganisms, plant pathogens and agriculture inoculants (*e.g., Rhizobia*).

Basically, two main lines of research and academic training are evident in Brazil:

- determinative microbiology: practiced mainly in the areas of clinical and food microbiology, where detection and identification of microorganisms are based upon standardized procedures, developed for the main classes of human, animal and plant pathogens;
- systematic microbiology, *lato sensu*: practice is restricted to few research groups, related to taxonomic and characterization studies of environmental microorganisms.

Clinical microbiology showed greater development compared to environmental microbiology. Several research groups with a long-term research tradition and international reputation are still active, and mainly linked to research in microorganisms of importance to public health, such as protozoa and viruses. Microorganisms associated to tropical diseases are still important research topics in Institutions such as Fundação Oswaldo Cruz (FIOCRUZ), Instituto Evandro Chagas and Universidade de São Paulo (USP). Consolidated groups in Bacteriology were identified at Instituto Adolfo Lutz (IAL), Instituto de Medicina Tropical da Universidade de São Paulo (IMT/USP) and Universidade Federal do Rio de Janeiro (UFRJ), whereas medical mycologists were identified at the DPUA, Universidade do Amazonas and IMT/USP.

Research in environmental microbiology is gaining strength, with emerging groups focusing on biomes from the Amazon Rainforest (Universidade do Amazonas), Central Cerrado (savannah, Universidade de Goiás) and Atlantic Forest (Universidade Federal de Pernambuco, Universidade Federal do Rio de Janeiro and Universidade de São Paulo).

In addition, specialists in microorganisms of agricultural, environmental and industrial importance as well a specialists in food microbiology are found in several centers, including EMBRAPA, IBSBF/Instituto Biológico, CNEN/PC-SP, SEMIA/IPAGRO (Piracicaba, SP), DTPE/CETESB (SP), INCQS/FIOCRUZ, Instituto de Pesquisas Tecnológicas (IPT, SP), Instituto de Tecnologia de Alimentos (ITAL, SP), Universidade Estadual de Campinas (UNICAMP), Universidade de Brasília (UnB) and Universidade de São Paulo (USP).

Know-how and resources in systematic microbiology, including installed capacity for polyphasic taxonomy, molecular systematics and culture-independent studies, needed in the analyses of complex microbial communities, require specific infrastructure and training. The expertise and application of these methods are still limited to a few research groups and institutions.

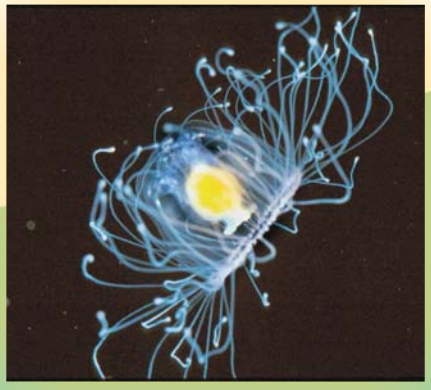
Lack of support to microbial culture collections was raised as a critical limitation to the development of environmental microbiology in Brazil. Important scientific collections, with holdings of microalgae, protozoa, bacteria, filamentous fungi, yeasts and cell lines, are mainly located in research institutes and universities of the Southeast and South regions. In contrast, the regions considered diversity-rich, such as the North and Mid-West, have a limited number of collections.

Data from a survey carried out between 1982 and 1989 listed a total of 36 collections, with holdings of algae (7), bacteria (18), filamentous fungi and yeasts (18), protozoa (4), viruses (1) and animal cell cultures (1). It remains, still, a large information void, given the limited data on the status and degree of conservation of holdings, documentation, availability of data on electronic format, human resources and, in general, on users, usage and research based on the holdings. In the SICol [7] Project, a recent initiative from the Ministry of Science and Technology (MCT), information on biological resource centers is being organized in an Internet-based system, integrating collections of interest for biodiversity, biotechnology, and industrial applications in the country.

Acknowledgments. Thomas Michael Lewinsohn for the opportunity of taking part in this survey and constant motivation. Manuela da Silva and Lyriam Lobo Rosa Marques for helping to organize and analyze the 1996 survey data. Charles Henrique de Araújo and Geraldo Sorte from CNPq/MCT for helping with searches in the Lattes databases in 2003. To the researchers and colleagues that contributed with data.

[7] System of Information on Collections of Biotechnological Insterest- SICol; http://sicol.cria.org.br.

Marine Invertebrates



Jellyfish *Turritopsis nutricula*

Photos: Alvaro Migotto

Giant hermit crab *Petrochirus diogenes*

Zoanthid *Palythoa variabilis*

Marine Invertebrates

Alvaro Esteves Migotto[1] & Antonio Carlos Marques[2]

The non-vertebrate organisms, denominated collectively Invertebrates, include 30-35 animal phyla. Most of these (16-18) are exclusively marine, eight are mostly marine and seven have marine representatives. Comprising still insufficiently known taxa, the description of new species and higher taxa of invertebrates are frequent, including new phyla, even for well-known regions and environments. As extensive portions of the oceans are almost unexplored, particularly the deep sea, it is not impossible that completely new ecosystems are unrevealed to the world, like the recent disclosure of the thermal vents. Concerning the South Atlantic, its marine fauna is among the poorest known in the world. Particularly for Brazil, there are many phyla without a single species record along its entire coast, whereas several other phyla are almost completely neglected.

The aim of this study was to compile and critically evaluate the available knowledge on biodiversity of invertebrates in Brazil, including lists of specialists, museums and collections, and general infrastructure, indicating deficiencies and suggesting the necessary actions. Data were gathered using a standard questionnaire distributed to selected systematists. Seven phyla that do not have specialists presently working in Brazil were not included.

The families and genera of the higher taxa included in this general survey were considered by most of the consulted specialists to be taxonomically well-established and appropriately reviewed, allowing their identification at the genus level, or even species level, in most cases. Identifications can be done based on literature, usually considered extensive.

The number of specialists in activity in Brazil is small for the geographical extent and diversity of organisms encompassed. Therefore, taxonomic training is seen as a topmost priority. Taxonomists can be qualified in relatively short periods (from two to four years), almost entirely in Brazil. For most taxa, the immediate employment of taxonomists by universities and institutes is an urgent priority.

A second priority is the improvement of museum collections mainly by collecting new material that is broadly representative of species in regional and worldwide scales, and cooperation with foreign researchers and institutes. The existing museum collections are almost always insufficient (non-existent in some cases). There is an urgent need to create conditions for maintaining these biological collections, not always possible in institutions without adequate tradition. Since most marine invertebrates need to be preserved and maintained in aqueous or alcoholic solutions, their collections demand large spaces, temperature control and constant care. Also, most specimens of several higher taxa are minute or microscopic, so that collections in public museums need to be curated directly by taxonomists themselves or by specialized technicians. Training of technicians can be carried out in Brazil in about two years. It is also important to promote the deposit of biological material by non-systematists, thereby ensuring their proper and long-term care in museums.

For most taxa, identification guides and manuals are lacking or deal with only part of the marine fauna. Brazilian researchers were considered to have enough expertise to produce such publications - whose financing should be also a priority - generally in a period from two to four years. Simultaneously to the publication of manuals and guides the production of taxonomic revisions and catalogs should be also encouraged as they are fundamental for biodiversity evaluations.

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[2] Departamento de Zoologia, Instituto de Biociências, Universidade de São Paulo, São Paulo, SP.

Practically all taxa were considered important for basic research, and should be contemplated in programs of systematics and biodiversity. The lack of knowledge of the Brazilian marine invertebrates and the potential importance of many of them in clarifying aspects of metazoan phylogeny are some of the reasons raised to justify their extended study. Indicator species (of environmental disturbances) are included in almost all the groups. Representatives of few taxa are used directly as a human food source in Brazil (Mollusca, Crustacea and, in low quantities, Echinodermata), but most are important items in the diet of economically exploited organisms, such as fish and crustaceans. Negative impacts on economical and public activities are attributed to many taxa that are either venomous or poisonous, parasites, components of fouling, or agents of corrosion of wooden and concrete structures. The field of marine biotechnology is extremely important, including research on natural products derived from marine animals. In a broader context the conservation of unique marine environments, like the coral reefs, are keystones for ecotourism and environmental education activities, but our lack of knowledge about their biodiversity could limit our ability to accomplish this desirable goal.

The number of species recorded from the Brazilian coast is still low, being difficult to estimate the actual number of species due to the scarcity of inventories and taxonomic studies. Nematoda is an example of an almost neglected taxon in Brazil, in spite of being very abundant and diverse in most benthic systems, occurring in densities generally larger than any other animal phylum. Most specialists consider that the number of undescribed and unrecorded species is high along the Brazilian coast, even in the most accessible marine environments. Studies employing recent methodology like DNA sequencing and ultrastructure analysis may contribute to uncover the so-called "hidden" biodiversity, consisting of, for instance, species complexes and sibling species. There is a general prediction that the number of species recorded from the Brazilian coast should double or triple, especially if collection efforts concentrate on less studied environments, such as the deep-sea fauna.

Few habitats can be considered as having a satisfactory degree of knowledge. In general, the benthic fauna of the intertidal and shallow infralittoral are relatively well-known due to the ease of access to these zones. Conversely, due to the need of oceanographic ships and special collecting devices, the continental shelf and slope are less collected and therefore inadequately known for the great majority of the taxa. The neritic and oceanic zones of the pelagic realm are also very little known, except for a few higher taxa. Estuaries and mangroves are relatively well-known for some taxa, although in general their fauna were considered insufficiently studied.

The marine fauna of the Northern coast of Brazil is so far the least studied and with scanty museum collections. In contrast, the Southeastern coast is unanimously considered the best known concerning its marine fauna, mainly due to the existence of several institutions and taxonomists dedicated to the study of marine environments and to the strong presence of research support agencies, like FAPESP. Natural history museums and universities are also concentrated in this part of the country. The consulted specialists also pointed out that a few higher taxa are well-studied or well-surveyed in the Southern and Northeastern coasts of Brazil, although in general these regions are considered poorly known.

Invertebrate neoextinctions have not been reported for the Brazilian coast, even though some species are considered endangered. Although neoextinctions appear to be rare among marine invertebrates, the lack of knowledge on marine biodiversity in Brazil precludes a better evaluation of the subject. Regional extinctions due to increasing environmental problems, like habitat loss and biological invasions, may be also largely undetected, especially in poorly studied areas.

We conclude that the urgent need of taxonomists in Brazil specialized in marine invertebrates imply that they should be adequately trained in modern taxonomy tools, and have conditions to maintain a team composed of databasing managers, scientific illustrators, technicians (specialized

in specimens preparations, DNA sequencing, MEV microscopy, etc.) and graduate students. Biodiversity programs should be adequately funded to assure that the existing taxonomists have conditions to work extensively on inventories, descriptions and phylogenetic analysis focused on the taxa in which they are specialized. At the same time, these programs should employ new taxonomists to work on the neglected taxa. The improvement of museum collections and the creation of new museums are another priority. These institutions should work as centers of excellence for taxonomic work, providing geographically broad and taxonomically representative specimen collections, specimen preparation and curatorship, identification services and databases as well as basic taxonomic work, as described above.

Terrestrial Invertebrates

Saturniidae moth caterpillar
Photo: Gustavo Mozzer

Bee *Epicharis* cf. *rustica*
Photo: Gustavo Mozzer

Butterfly *Myscelia orsis*
Photo: José Sabino / Natureza em Foco

Terrestrial Invertebrates

Carlos Roberto Ferreira Brandão[1], Eliana Marques Cancello[1]

& Christiane Izumi Yamamoto[1]

We present detailed information and discuss the state of knowledge in Brazil on earthworms (Annelida), on Arthropoda Arachnida (spiders in general and Mygalomorphae, in particular harvestmen, mites and scorpions), on Myriapoda (centipedes and millipedes); among the Insecta, on Odonata (dragon-flies), Isoptera (termites), Coleoptera (beetles in general), and especially Cerambycidae (longhorn beetles), Elateridae (click beetles) and Curculionidae (weevils); among the Hymenoptera, on Ichneumonoidea (parasitic wasps), Sphecidae (digger wasps) and Formicidae (ants). Moreover, we added information taken from the recent literature and supplied by colleagues on groups not covered by the questionnaires used for this survey. We also make comments on the best collections in the country and the priorities indicated by specialists to improve the study of terrestrial invertebrates.

The taxa discussed here include species considered important as agroecosystem pests in managing agroecosystems, as vectors of pathogens in agroecosystems, as pollinators and/or parasites/predators of other pests, as parasite vectors of human beings and animals, as venomous species for the identification of new chemicals, as rare or threatened species as good environmental impact indicators and as good tools in education programs.

All specialists that have contributed to this diagnosis considered their groups of speciality as prioritary for research programs on Systematics. Surveying the information gathered by each of the consulted specialists, one is able to evaluate the relative importance of the considered taxa and to obtain indications on how to improve their knowledge, and also how this information can contribute to formulate conservation politics.

Northeast Brazil was indicated as the poorest known region by all specialists according to all criteria used. Correspondingly, the Northeastern Caatinga biome was also ranked as the worst known Brazilian biome. The Mid-Western region was ranked as the second lowest regarding knowledge on and collecting efforts for most invertebrate groups. Accordingly the Pantanal and the Cerrado have been classified as poorly known by most specialists. The Northern region of Brazil appeared in an intermediate position, as some of the investigated groups can be considered reasonably well known in Amazonia. In Southern Brazil, most invertebrate groups were considered reasonably known, although some taxa have never been systematically collected there. The only Brazilian region with positive rankings on both criteria was the South, and therefore the Atlantic Forest biome received equivalently high rankings.

Of the taxa emphasized in this study, only the ants have been systematically investigated in higher montane habitats.

Further electronic information on the Brazilian terrestrial invertebrates can be obtained in the following sites:

http://www.bdt.org.br/bdt/biotasp/planaria.htm (on flatworms).

http://www.bdt.org.br/bdt/biotasp/indnema.htm (on nematodes).

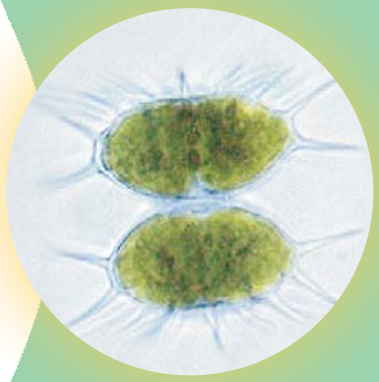
http://www.bdt.org.br/bdt/biotasp/insecta (on insects in general).

Some recent texts that complement this information are Brandão and Cancello (1999) and Guedes (1998).

[1] Museu de Zoologia, Universidade de São Paulo, São Paulo, SP.

Freshwater Organisms

Zooplankton *Daphnia laevis* - Photo: Evandro Moretto



Phytoplankton *Staurastrum setigerum*
Photo: Ana Cláudia Peres

Tropical royalblue waterlily *Nymphaea elegans*
Photo: Magno Botelho Castelo Branco

Freshwater Organisms

Odete Rocha[1]

Freshwater invertebrates belong to a variety of taxonomical categories, although in most cases the freshwater component is less diverse than the marine component and, in general, the freshwater organisms are smaller, less colorful and less conspicuous than their marine counterparts. Freshwater biodiversity is also far less known than marine biodiversity. As a consequence, the UNESCO Diversitas Program has chosen Freshwater Biodiversity as one of its special targets for studies in the near future.

Based on information gathered among specialists and literature review contributors, the following diagnosis on the present knowledge on Brazilian Freshwater Invertebrates Biodiversity is presented.

There is no information available with regard to the diversity of Virus, Bacteria and Protozoa in Brazilian freshwaters. Some fragmentary information was compiled, but it was impossible to come up with any estimate of numbers of species or indeed genera, not even as a rough guess. There are very few researchers working with taxonomy and ecology of these groups, and none is a full-fledged specialist. It will be necessary to train a number of researchers to cover these important groups. They are of great importance from both economical and general scientific viewpoints. Human resources, literature and collections are lacking.

There are 2,331 species of freshwater fungi known in the world. In Brazil there are 414 known species, 141 belonging to the Stramenopila, 180 summing up the Acrasiomycota, Dictyosteliomycota, Myxomycota and Plasmodiophoromycota, and 93 in the Chytridiomycota. There are research groups in São Paulo (Institute of Botany and State University of São Paulo at Botucatu) and in the Federal University of Pernambuco. The experts deem that training and engagement of researchers at jobs where they can continue the work are the main priorities for advancing knowledge of Fungi. They point out that a specialist can be qualified in four to ten years, but that a technician could be trained in about two years in order to collect, sort out and identify common species.

Algae are a large and diverse group in freshwaters. There are around 10,000 species identified in Brazilian freshwaters: 800 Cyanophyceae, 3,500 Chlorophyceae, 1,200 Bacillariophyceae, 2,000 flagellates belonging to several groups, 50 Rodophyta and some other groups. They are extremely important in all freshwaters because they are the main primary producers and therefore the basis of all food chains. There are a number of taxonomists in Brazil. An important research group is found in the Botany Institute of São Paulo; in many other Brazilian institutions there are specialists, for example: Federal University of Paraná, Curitiba; Natural Science Museum in Porto Alegre, Rio Grande do Sul; State University of Ponta Grossa, Paraná; Federal University of Santa Catarina, Florianópolis; National Museum, Rio de Janeiro; Federal University of São Carlos, and others. The researchers consider that priority actions to increase knowledge include the improvement of collections, literature, and multiplication of well-trained human resources. There are important collections and literature available in the Botany Institute of São Paulo, the National Museum in Rio de Janeiro, Federal University of Paraná and Natural Science the Museum in Porto Alegre. Specialists expect that the known number of species can be at least tripled by a comprehensive biodiversity program.

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Flowering plants or angiosperms are of common occurrence in Brazilian freshwaters occupying different habitats in aquatic environments, either rooted, submersed or floating. A number of species are known in Brazil, but it is not possible at present to gather information as a whole. At a guess, at least 100 species can be found in Brazilian freshwaters.

For the animal invertebrate component, we found that at least 3,134 species have been recorded in Brazilian freshwaters. They can be grouped as:

I) A diversified but small group constituted by ten small taxa represented by less than 100 species each, totaling 365 species (44 Porifera; 9 Cnidaria; 92 Turbellaria; 2 Nemertinea; 63 Gastrotricha; 10 Nematomorpha; 10 Bryozoa; 61 Tardigrada; 74 Annelida);

II) Rotifera, with 467 species known in Brazil;

III) Mollusca (Gastropoda and Bivalvia), summing 308 species;

IV) Acari (Hydracarina) with a total of 332 species;

V) Crustacea, with a total of 365 species;

VI) Insecta, with 1,297 species recorded for freshwaters.

There are important invertebrate groups for which there are no Brazilian specialists, and no inventory work is being carried out at the moment. These include Nematoda; Platyhelminthes Turbellaria; Nemertinea; Gastrotricha; Nematomorpha; Bryozoa; Hydracarina (aquatic mites); Syncarida; Ephemeroptera; Trichoptera; Coleoptera; Hemiptera; several families of Diptera; Annelida Hirudinea among others. The problem is further aggravated by the fact that foreign scientists, some in the 19th century, described many species and the holotypes are in collections outside Brazil hindering the comparisons required for correct identification in many groups.

Planktonic groups as Rotifera, Cladocera, and Copepoda are better known than the benthic forms. Among benthic organisms some, as the Crustacea Decapoda, are better known, because they are important in the trophic chains, they have large sizes and can be commercially cultivated or harvested. Another noticeable trend is that groups relevant to public health are better known. That is especially the case of mollusks and insect vectors or transmitters of diseases. For such groups there are sufficient researchers in the country and the priorities should be to motivate the already trained young scientists to carry on taxonomical work – through job opportunities – and to extend – to Brazil as a whole – research programs such as that currently fostered by FAPESP in the State of São Paulo (the Biota-FAPESP program).

All researchers consulted during the gathering of information for this review emphasized the need to train more people, to engage trained researchers in jobs where they can continue their research work, to improve collections and geographical coverage, to improve literature and to produce documentation, keys and manuals for identification. With regard to the latter, the importance of help from foreign experts is pointed out for many groups.

According to the estimates compiled here, there should be at least 8,500 species not yet recorded or described (around 1,000 Coleoptera, 500 Heteroptera and 5,000 Diptera, 500 crustaceans, 500 rotifers plus about 1,000 species in all other taxa) not counting Bacteria and Protozoa. For fungi, algae, mosses, ferns and flowering freshwater plants, the estimate of 20,000 species yet to be identified is probably a conservative figure. It can be said that less than 30% of freshwater biodiversity in Brazil is known so far.

The situation of collections for most groups is of great paucity and even of complete absence for some groups. Notable exceptions are, for instance, the collection of Decapoda in the Zoological Museum of the University of São Paulo and the Porifera collection in the Natural Sciences Museum in Rio Grande do Sul. For most taxa the collections are dispersed among many institutions and incomplete. Financial resources and training of specialized technicians are needed for proper maintenance of the collections. There are problems in maintaining the already existing collections. Some museums lack the necessary infrastructure, taxonomists and curators for the required tasks.

Groups with no known organized collections include the Turbellaria, Bryozoa, Nemertea, and Oligochaeta. There are specimens in university departments and some groups are in personal collections, such as the Gastrotricha and Lepidoptera.

There is an urgent need for the creation of complete collections by extensive sampling in the whole country and producing reliable reference collections, thus making materials and information more accessible.

A list of current researchers of freshwater groups was obtained by this evaluation, although incomplete. It is clear in general that there are far too few workers. It was not possible to ascertain whether researchers are doing taxonomic work full-time, part-time or in their spare time, although most will certainly fall in the two last categories because they are in universities and overwhelmed with teaching and administration. Moreover, most researchers have inadequate technical and clerical support, if any at all. Some researchers are able to identify freshwater organisms, but work preferably on marine forms.

There are important questions to be answered in the near future, as for example: what are the estimates of endemism of species or of higher taxonomic levels? How adequate are collections and how accessible are the types? What proportion of these is held overseas? Is description and surveying of unknown taxa proceeding at too slow a pace? Can it be accelerated? The search for information to deal with these questions is already under way.

Vertebrates

Photos: José Sabino / Natureza em Foco

Red-legged seriema *Cariama cristata*

Poison dart frog *Dendrobates leucomelas*

Jaguar *Panthera onca*

Characin fish *Brycon hilarii*

Vertebrates

José Sabino[1] & Paulo Inácio Prado[2]

Brazil is, certainly, the richest country in the world in terms of vertebrate species if considered the tetrapods and fish together. This condition imposes on us the ethical responsibility of understanding the magnitude of this richness. The knowledge of this diversity is essential for the exploration, responsible use and conservation of this rich patrimony.

The present study resulted from a request by the Secretary of Biodiversity and Forests of the Ministry of the Environment (SBF-MMA) within the National Biological Diversity Strategy Project. The diagnosis of the diversity of vertebrates is part of a broader project (Synthesis of the Knowledge of the Biological Diversity of Brazil), funded by the Global Environmental Facility and supported by the United Nations for the Development Program (UNDP), the Brazilian Agency of Cooperation (ABC), and the Brazilian Council of Research (CNPq).

The goal of this document was to provide a first profile of the current knowledge on vertebrate diversity in Brazil. The main aspects considered were species richness (by taxa and biomes), collections, specialists, and literature available, and also priorities for the near future. In this synthesis, we discussed aspects of the known fraction of vertebrate diversity of the country and we tried to indicate ways to better deal with this admirable group of animals. Examining different data sources, we traced a profile of the existing infrastructure, and we pointed out knowledge gaps. Also we indicated the groups that need more specialists to improve the taxa knowledge, and which areas in the available bibliography should be expanded. This work is only an initial characterization of the current knowledge on diversity of vertebrates in our country, with diagnosis of the taxonomic richness, state of the collections, and bibliography. To produce such a diagnosis 62 specialists of different taxonomic groups were consulted, and additional data were gathered from publications, databases, and the Internet.

Many specialists consulted by the project as well as the specific literature that they emphasized showed the enormous diversity of Brazilian vertebrates, considered the largest of the world (Table 1). This megadiversity is still poorly known and a substantial part of this is critically threatened by human activities, which reinforces the need and urgency of expanding the knowledge of this natural patrimony. For instance, Brazil has the largest richness of freshwater fish and mammal species of the world, the second largest diversity of amphibians, third of birds and fifth of reptiles (Table 1). However, the exact number of Brazilian vertebrate species is still unknown, especially because there are extensive areas that have not been inventoried yet. Even in areas with larger collection efforts, new species are regularly described, including those belonging to conspicuous groups, as primates and birds.

Knowledge on vertebrate diversity varies widely among groups, geographic area, and biomes. Roughly, there is more and better information about birds and mammals, and the Atlantic Forest is the most sampled biome. The recent sampling and data compilation for poorly-known biomes (for instance, Caatinga, Cerrado, Pantanal, and Amazon Rainforest), should entail a great increase in species richness of Brazilian vertebrates, particularly for bony fishes, amphibians, and reptiles.

The number of specialists varies among taxonomic classes, but, as a general rule, there are good experts in all classes, although not in sufficient number. For most classes, there are trained

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experts not working in research institutions. Collections are, in general, accessible and partially adequate for taxonomic research. The three most important institutions, with extensive collections for all groups, are the Museu de Zoologia da Universidade de São Paulo USP (MZUSP), Museu Nacional (MNRJ), and Museu de Ciência e Tecnologia da Pontifícia Universidade Católica do Rio Grande do Sul (MCP).

The informants of the project emphasized the urgent need for improvement of collections, and engagement of researchers and technical personnel. The collections can be improved through sampling of poorly known biomes and groups. Additionally, publication of identification resources (field guides, keys) was considered urgent for almost all Brazilian vertebrate groups.

Resources and experts for the study of vertebrate diversity are highly concentrated in Southern and Southeastern Brazil, the most populated and industrialized regions, and also the worst preserved. Thus, improvement of institutions and engagement of specialists are urgent needs for the other regions of the country (North, Northeast and Mid-West). However, the political principles to minimize regional differences should be established by the production quality of the research groups or institutions that would request resources.

Table 1. Diversity of vertebrates (number of described species) in Brazil and in the world, percentage of endemic species in Brazil, and country position in the biodiversity world ranking. Some updated values differ from Lewinsohn and Prado (2002).

Group	N species in the world	N species in Brazil	Endemism Brazil (%)	Rank diversity Brazil
Agnatha	83 [1]	04 [2]	-	-
Chondrichthyes	960 [3]	141 marines [4] 3 freshwater [5]	- 23% [5]	 -
Osteichthyes	ca. 23,800 [6]	1,300 marines [4] ca. 3,000 freshwater [7]	ca. 10-20% [8] -	- 1
Amphibia	ca. 4,800 [9]	ca. 600 [10]	57 % [11]	2 [11]
Reptilia	ca.10,400 [9]	468 [11]	37 % [11]	5 [11]
Aves	9,700 [12]	1,688 [13]	11 % [11]	3 [11]
Mammalia	4,650 [14]	525 [15]	25 % [15]	1 [11]
TOTAL	**ca. 54,393**	**ca. 7,739**	**-**	**1**

Sources:

[1] Potter, 1995.

[2] Mincarone, 2002; Osvaldo T. Oyakawa, personal communication.

[3] Stevens and Last, 1995.

[4] Buckup, P.A. and N.A. Menezes (eds.), 2002**. Catálogo de Peixes Marinhos e de Água Doce do Brasil**. Provide a list of the Brazilian marine and freshwater fish species, periodically updated.

URL: http://www.mnrj.ufrj.br/catalogo/ (accessed in July, 2003).

List of marine and freshwater species of the world (edited by Froese, R. and D. Pauly, 2003. **FishBase**, World Wide Web Electronic Publication). URL: http://www.fishbase.org (accessed in August, 2003).

[5] Rosa, 1985 and personal communication, for freshwater stingrays.

[6] Weitzman, 1995.

[7] Menezes, 1996 (conservative estimated for number of Brazilian freshwater fish species).

[8] Castro and Menezes, 1998. Endemism rate extrapolated for the State of São Paulo, supplied by these authors, and added to information provided by Rodrigo Leão de Moura (personal communication).

[9] Zug et al., 2001.

[10] Haddad, 1998 (estimated species).

[11] Mittermeier et al., 1997.

[12] Silva, 1998.

[13] Comitê Brasileiro de Registro Ornitológico, 2003. Primary list of Brazilian birds, periodically updated. URL: http://www.ib.usp.br/cbro (accessed in June, 2003).

[14] Vivo, 1998.

[15] Fonseca et al., 1996. Added the species *Mazama bororo*, described by Duarte (1996).

Recommendations

Among all of the aspects exposed in the present study, it is possible to summarize the following recommendations:

- To increase collections through the incentive of general inventories and directed collections which emphasize areas, biomes and poorly-known groups with priority in the workshops for evaluation of the different Brazilian biomes (for detailed information on these areas, including maps, see MMA, 2002);
- To stimulate production and publication of species lists, taxonomic revisions, keys and field guides, with emphasis on badly-documented groups;
- To stimulate publication of keys, manuals and field guides, which allow the identification of species by specialists and non-specialists;
- To increase the number of specialists, through the training of new professionals, and to promote policies for placement of those already graduated but not absorbed by the scientific institutions, inclusively employing the curators for zoological collections (a gap highlighted by several project contributors);
- To diminish the regional disparities on distribution of human resources and material for studies on diversity of vertebrates, strengthening the institutions and stimulating the researcher's fixation in less-assisted areas such as Northern, Northeastern and Mid-Western Brazil. However, such support should not be based solely on material needs and lack of knowledge on the badly-inventoried biomes, but it should be also outlined by the previous production and merits of the scientist, research group or institution requiring the resources;
- To create distinct mechanisms for employing and settling researchers in teaching and research institutions in the Mid-West, North and Northeast regions, stimulating the creation and expansion of groups intended to investigate the diversity of vertebrates in those less-sampled areas, which bear significant parcels of their biota still to be properly inventoried;
- To overcome shortages of the major bibliographical and biological collections, regarding the need of qualified personnel (including technicians), facilities and cataloguing. Another aspect considered indispensable for collections presupposes the increasing and installation of collections and laboratories, which include tools for analysis of genetic and acoustic material (the latter applying for amphibians and birds);
- To create computerized databases, such as the "Catálogo de Peixes Marinhos e de Água Doce do Brasil" ("Catalogue of Marine and Freshwater Fish of Brazil") and the "Comitê Brasileiro de Registro Ornitológico" ("Brazilian Committee of Ornithological Records"), as means of facilitating consultation by the scientific community;
- To use the Internet to disseminate the information already available in electronic format and to stimulate the compilation of the information not digitized yet for this purpose, emphasizing scientific collections, researchers and bibliography, periodically updated;
- To create and establish means to access the available information on diversity of Brazilian vertebrates, as a support for teaching and researching;
- To direct resources for publication of scientific periodicals and books focused on the fauna of Brazilian vertebrates;
- To produce material to propagate information and to sensitize the public about the importance of Brazilian vertebrates. The edition of books, wildlife guides and articles in different media, based on scientific knowledge, is considered very important in the process of popular education;

- To stimulate the production of educational material directed at basic school levels and teacher training, based on examples from Brazil's vertebrate fauna, and adapting the language to those specific public. To emphasize the biology of species of vertebrates with negative reputation among the public (e.g., sharks, piranhas, toads, snakes, and bats).

We hope that these recommendations can be implemented, and that they contribute for improving the scientific community's knowledge on the extraordinary diversity of Brazilian vertebrates. We also expect that such increase in knowledge will foster the development of new means of responsible and sustainable use of vertebrate biodiversity. Finally, we hope that scientists share their knowledge with the Brazilian society more and more, thus popularizing the importance, grandiosity and beauty of the Brazilian vertebrates, educating several segments of the society and mobilizing them for the defense and conservation of this precious natural resource.

Terrestrial Plants

Gymnosperm *Podocarpus lambertii*

Angiosperm *Bromelia antiacantha*

Bryophyte *Lophocolea sp.*

Photos: George Shepherd

Terrestrial Plants

George John Shepherd[1]

From the viewpoint of terrestrial plants, Brazil is the most biodiverse country in the world and contains from 15 – 20% of the known species. This represents a substantial fraction of our globe's total biodiversity and gives Brazil both a privileged position and a heavy responsibility in the exploration, exploitation and preservation of world biodiversity.

This report discusses what is known about this diversity and attempts to evaluate Brazil's capacity to deal with it in terms of manpower and infrastructure.

Terrestrial plants are treated here as four major groups – Bryophytes, Pteridophytes, Gymnosperms and Angiosperms.

The **Bryophytes** are relatively small, delicate plants, which reproduce by spores and prefer moist and shady habitats. In Brazil, the bryophytes are represented by about 3,100 species – approximately 22% of the total species known. The country thus possesses a very high proportion of the world bryophyte flora. The number of professional or serious amateur bryologists in Brazil is very limited, with perhaps only nine or ten researchers in permanent positions. Although the total number of species can be estimated, bryophyte collections for Brazil are still very limited and a sizeable proportion, including most of the type material essential for nomenclatural studies and taxonomic revisions, are deposited in herbaria in Europe or in the United States. Knowledge on regional distributions and occurrence of species in the major biomes are still very incomplete and it is not possible to provide accurate data. It is clear, however, that the major regions of bryophyte diversity are in the south and southeast of Brazil and not in the lowland Amazonian regions which tend to be comparatively poor in bryophytes. At present, the bryologists working in Brazil are capable of identifying much of the material collected in the country, but their limited numbers make it difficult to deal with the demand for identifications as well as carrying out original taxonomic research. Although this group is not of great economic importance, it is of considerable interest from an ecological and evolutionary viewpoint. Major recommendations for this group include:

- An increase in the total number of researchers working with the group.
- Formation of new researchers, which can be partially completed within Brazil. However, the number of potential supervisors is very limited and it may be necessary to send students for overseas training, especially where a recognised expert is available to supervise them.
- Considerable investment in new collections and studies of geographical distributions.
- Conservation of these organisms, which depends on the conservation of entire habitats, especially forests, since live collections and storage of spores are not viable options for conservation.

The **Pteridophytes** are a group of larger, vascular plants which, like bryophytes, reproduce by spores and prefer relatively humid, shady habitats. This group is rather less diverse in Brazil, with perhaps about 1,400 species, representing about 10-12% of the world total. The number of researchers working on pteridophytes in Brazil is also very low. The estimate of overall diversity is probably reasonably accurate, but there are still great taxonomic difficulties with some groups. Knowledge of regional distribution and occurrence in different biomes is somewhat better than that for bryophytes, but still very limited. Like the bryophytes, the greatest diversity is found in the South

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and Southeast of the country and not in the lowland Amazonian forests which tend to be relatively poor in species. Pteridologists working in Brazil are capable of identifying the majority of material found within the country, but once again, tend to be overwhelmed by the quantity of material to be identified and the number of groups still requiring taxonomic revision. Although this group is of limited economic importance (mainly ornamental plants), it is of considerable interest from an ecological and evolutionary viewpoint. Major recommendations:

- An increase in the total number of researchers working with the group.
- Formation of new researchers, which can be probably mainly completed within Brazil. However, the number of potential supervisors is very limited and it may be necessary to send students for overseas training, especially where a recognised expert is available to supervise them.
- Considerable investment in new collections and studies of geographical distributions is required.
- Conservation of these organisms, which depends on the conservation of entire habitats, especially forests. Although some ferns are commonly cultivated, there are no comprehensive live collections and some of the other groups of pteridophytes are more difficult to cultivate. Spore storage is probably not a viable option.

The **Gymnosperms** are predominantly a woody group, with most species forming moderate or large trees. There are probably only 14-16 species of gymnosperms in Brazil, representing only about 2% of the world total. This is not surprising as this group is the commonest group in cold-temperate climates. There appear to be no Brazilian specialists working exclusively with this group, but most of the species can be identified without great difficulty, except for the genus *Gnetum* in the Amazonian area. Economic value is chiefly confined to *Araucaria* (wood) and *Ephedra* (ephedrine production), but the genera *Gnetum*, *Ephedra* and *Zamia* are of great interest from an evolutionary point of view. Main recommendations:

- Training and formation of specialists in taxonomy of the group is probably not justified given the small number of species, but investigation of genetic variation and preservation of germplasm of *Araucaria* natural populations should receive some priority.
- Strong efforts should be made to investigate the ecology and reproductive biology of *Gnetum*, *Zamia* and *Ephedra* to ensure adequate protection for natural populations of these genera given their great evolutionary significance and relative rarity world-wide.

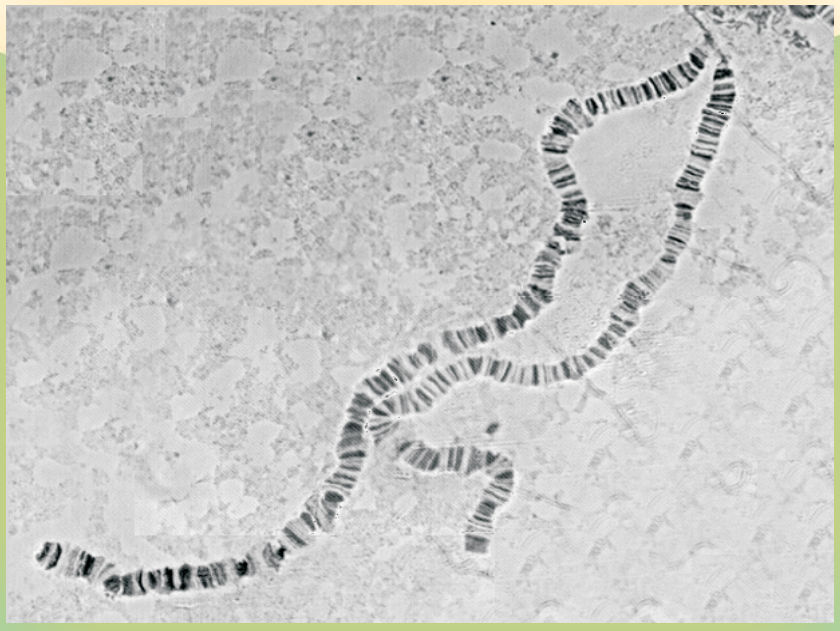
The **Angiosperms** (flowering plants) are by far the most abundant and dominant of all the terrestrial plants. The Brazilian flora probably contains about 50,000 or more species, representing about 16-20% of the world total. There are probably around 200 researchers in Brazil working actively with the taxonomy and identification of this group of plants, with a further group capable of identifying at least commoner species, and other researchers working with ecology, reproductive biology, cytology and genetic variation. Although this number of researchers is impressive when compared with those working with other groups, it is far from sufficient considering the large size of this group and the overwhelming economic and ecological importance of these plants. No recent floras or identification manuals are available for the whole Brazilian flora and it is unlikely that such an undertaking can be contemplated in the immediate future. At this moment, a strategy of developing floras at state level or more restricted areas seems to be a consensus among researchers in Brazil, and attempts to produce a complete flora would require a huge expenditure of time and efforts, which are simply not feasible at present. Knowledge on geographical and ecological distributions is much more abundant than in other groups but it is not available in a concentrated and systematic form, and it is difficult to provide accurate data for regional and biome-level diversity. Major recommendations for this group are:

- A high increase in the number of researchers working with this group. Many large families have very few taxonomists or researchers capable of identifying them accurately.
- A lot of effort to be devoted on improving existing collections and their preservation, and on improving the distribution of collections, which are still grossly uneven in many regions. Although this group has been more heavily collected than any other group of terrestrial plants, collections are still manifestly inadequate to estimate total flora, and regional or local biodiversity.
- Support should be given to flora projects at state and local level, but the total number of taxonomists available is insufficient to permit simultaneous execution of all flora projects now being planned.

A number of recommendations are equally applicable to all of the groups considered up to now:

- Investment in formation of human resources is highly necessary if Brazil is ever to become reasonably self-sufficient in managing and identifying its own biodiversity. For many groups, especially in the Amazonian region, the only taxonomists capable of identifying to species level live and work in Europe or in the United States, and only visit Brazil sporadically.
- Training and development of new techniques to speed taxonomic and floristic studies should be a high priority. The use of computerized methods for taxonomic description and identification show enormous promise, but require a massive investment in training and resources in order to be successfull.
- A large investment in physical infrastructure and informatization of collections is necessary if these are to adequately serve their purpose of documenting biodiversity and as research instruments. Much of the information required for current decisions on biodiversity management and exploitation can be probably only obtained by an extensive and urgent program of herbaria and other collections databasing.
- Progress in taxonomy and ecology for many groups depends on the availability of identification manuals. Materials suitable for teaching at undergraduate and post-graduate level are almost non-existent for many groups and production of such manuals should have high priority. Elaboration of well-illustrated, interactive, computerised identification keys could be of great use in teaching and training, and then they should be encouraged.
- Repatriation of data and images of type specimens and other materials held in herbaria and other collections abroad would be enormously useful in speeding and facilitating taxonomic research of Brazilian plants. Consideration should be given to establishing a national effort to remedy the lack of such materials and to make them widely available through the Internet or on electronic media such as CD-ROMs.
- The distribution of researchers and collections throughout the country is very uneven, with a great concentration of workers in the Southeast and South. A strong effort is required to increase the number of taxonomists and ecologists working in hyperdiverse regions such as the Amazon basin and the Mid-West region.
- The use of molecular techniques in plant systematics is currently “fashionable” and of great importance, and it needs to be further developed in Brazil. However, this should not divert efforts and resources from more basic activities of collecting and alpha taxonomy, which form the basis for all other biodiversity studies and supply the raw materials for more sophisticated applications.

Genetics



Polytenic chromosomes of fly *Drosophila mediopunctata*
Photo: Galina Ananina and Louis Bernard Klaczko

Genetics

Louis Bernard Klaczko[1] & Roberto Donizete Vieira[1]

Genetics can be didactically divided into five areas according to the methods used and the studied material: Cytogenetics; Molecular Genetics; Biochemical Genetics (Isozymes); Quantitative Genetics (Quantitative Traits); and Population Genetics (Polymorphisms).

In order to assess the present state of knowledge on genetic biodiversity in Brazil, we prepared a questionnaire with seven forms. The first form collected data on the person giving the information (researcher), staff members and institution. The last one obtained bibliographic references of the group's work. The other five forms were addressed to each of the Genetics areas mentioned above.

Each form could be filled out with information on studied taxa, Family and Order identification, studied localities, habitats, relevant reference citations, and a short description of the main results and conclusions. Furthermore, the fields on objectives and methods were designed to acquire guided answers among several alternatives. For the objectives, we provided a series of alternatives that progressively increased the complexity of the genetic variability characterization. For example, in the interspecific studies, the following choices were provided: characterization of species, comparisons among species, and phylogenetic inferences. For the methods, likewise, we attempted to make a list which showed increasing complexity and/or degree of information.

In order to collect the data and to assess the usefulness of the prepared forms, we initially used the published Summaries of the 42nd Congress of the Brazilian Society of Genetics (SBG) (1996), in which Genetic Biodiversity was the main topic. These summaries were used to fill out a total of 242 forms: 142 on Cytogenetics; 34 on Isozymes; 40 on Molecular Genetics; 22 on Quantitative Traits; and 4 on Polymorphisms.

After testing the questionnaire using the Congress Summaries, it was sent to 80 scientists, heads of research groups in Brazil. Their names were chosen from the above summaries as well as from the Research Group Directory and the Prossiga System, both from the Conselho Nacional de Ciência e Tecnologia – CNPq.

Of the 80 scientists who were contacted, 33 filled out the questionnaires. Approximately 60% of the answers came from the state of São Paulo, 10% from Rio Grande do Sul, and the remaining from Minas Gerais, Rio de Janeiro, and Paraná. In total, 106 forms were returned: 42 on Cytogenetics; 17 on Isozymes; 24 on Molecular Genetics; 20 on Quantitative Traits; and three on Polymorphisms. Since there were very few forms on polymorphisms, they will not be discussed here.

Cytogenetics

Cytogenetical methods can be divided into three or four categories according to the complexity and/or quantity of information. Analyzing the data from the SBG summaries we found among 141 forms: 36% using the simplest methods; 57% using banding or similar techniques (which are more informative), and 6% using techniques with higher definition (polytenic chromosomes and *in*

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situ hybridization). In the data received from the scientists (43 forms), we found: 38% using *in situ* hybridization; 14%, polytenic chromosomes; 39%, some kind of banding technique, and 12% with only simple karyotype or chromosome counting.

Regarding the objectives, 33 SBG summaries were related to the study of interspecific variation: 12 aimed phylogenetic inferences and the remaining 21 only intended to make comparisons among species. Twenty-five SBG summaries were related to intraspecific studies: 18 were related to the description of intrapopulation variation and comparisons among populations; three investigated geographic variability; and four searched for clines. Of these summaries, 52% could be said to have solely descriptive objectives, and 17% made an attempt to explain the results.

Among the answers given by the scientists, 37 were related to interspecific studies. The majority of these (81%) were studies intending to make phylogenetic inferences and only a small portion (19%) was limited to simple comparison of species.

Isozymes

For a study on genetic variability be considered of good quality, the number of *loci* should exceed 20. Studies containing between ten and 20 *loci* are considered reasonable, and those containing fewer than ten *loci*, insufficient. Similarly, a number higher than 20 analyzed systems is considered excellent; between ten and 20 systems, good; and between five and ten systems, fair.

The 34 SBG summaries of isozyme studies reported the use of 132 systems, with an average of 8.1 per paper. In total, 36% used fewer than five systems; 36% between five and ten; and 34% more than ten. The average number of *loci* per paper was 12.1, where 42% of the papers analyzed fewer than ten systems; 32%, between ten and 20 systems; and 26%, more than 20 systems.

Among 17 forms filled out by the scientists, 180 systems were used, averaging 11.3 per work –11% had fewer than five systems; 33%, between five and ten systems; and 50%, between ten and 20 systems. The average number of *loci* per work was 20. Nine forms reported from ten to 20 *loci* and seven forms more than 20 *loci*.

Among the 34 SBG summaries, 11 intended to study interspecific variation, from which only four intended to make phylogenetic inferences. From the remaining 22 summaries, five had the objective of comparing populations, and all the others (72%) were only descriptive.

Among the 17 answers obtained from leading scientists, ten were related to interspecific studies, from which half of them intended to make phylogenetic inferences and the other half intended to make comparisons between species. Among the remaining seven summaries, five intended to study the structure of populations or to search for clines and correlations with environmental variables, and only two were solely descriptive. Overall, 40% could be considered as essentially descriptive.

Molecular Genetics

The analysis of 40 SBG summaries objectives showed that among 23 related to interspecific variability, 83% aimed to obtain phylogenetic inferences. In total, 25% had descriptive goals. On the other hand, among the forms filled out by the scientists, 75% were related to interspecific study and all of them aimed phylogenetic inferences, while only 17% had merely descriptive goals.

Among 38 SBG summaries, 53% used DNA sequencing –the most sophisticated and informative current method of Molecular Genetics, 26% used RFLP or microsatellites or other techniques, and 24% used RAPD (the least informative method). Among the 24 forms returned by the scientists, 74% used DNA sequencing, 25% used RFLP, microsatellites or others, and only 4% used RAPD.

Quantitative Traits

Among 22 SBG summaries examined, 50% used multivaried statistical analysis, and 27% performed experiments in controlled environmental conditions or analyzed inbred strains. On the other hand, among the 20 responses from the scientists, 60% reported the use of multivaried tools and 25% used artificial selection, markers, analysis of strains or experiments under controlled environmental conditions.

Among the 20 forms filled out by the scientists, ten were related to interspecific analysis: seven to phylogenetic inferences and hybrid studies, and three to comparison among species. From the remaining ten forms: four aimed to estimate heritability; five were descriptive (intrapopulational or geographic variation); and one intended to study the biological meaning of a trait. Thus, 35% were essentially descriptive.

Conclusions

The main difficulty in conducting this kind of study is to obtain a satisfactory form return rate. Having this in mind, we used a double process to collect information for this assessment: the SBG summaries and the representative leading scientists. With both sources, 33 of the 80 forms (41%) were returned to us. This rate is quite satisfactory, since this kind of study frequently has a 10% return rate.

To fill in remaining gaps and to ensure that the gaps found were real and not due to insufficient data, we consulted the Biological Abstracts (1998 and 1999) and the Zoological Record (vols. 122 to 135). We performed a bibliographical study for the main plant and animal groups using appropriate key words to find genetic biodiversity research in Brazil.

The greatest difficulty was to characterize the information from a biogeographical point-of-view. The information we obtained was very heterogeneous or imprecise in this regard. Even so, it was possible to analyze the data in a qualitative manner, considering the Brazilian states globally. However, one must be cautious in drawing conclusions from this information alone.

We can consider the states of São Paulo, Minas Gerais, Rio Grande do Sul, Mato Grosso do Sul, Rio de Janeiro and Pará as the most studied states. Similarly, as we noticed before, in general the coast (Atlantic Forest, coastal rivers, Paraná River basin), the Amazon region (forest and river basin) and the Cerrado – in the states of São Paulo, Minas Gerais and Mato Grosso do Sul – were the most studied biomes. There were studies in the Pantanal, although less intensive. Finally, the regions which appear to be the least studied, or never even mentioned, are the Caatinga and the central region, especially the states of Goiás, Mato Grosso, and Tocantins.

Examining the data as a whole, summaries and researchers' responses, we note that the most studied taxa among animals are insects – mainly Diptera and Hymenoptera –, fish, mammals – particularly rodents and primates –, and birds. In contrast, major gaps for animals are the echinoderms (sea urchins and starfish), the annelids (round worms), and the cephalopods and Pelecypodae among the gastropods. Even among the mammals, a relatively well-studied taxon, some gaps were observed such as the absence of studies on Felidae (cats in general). No studies on genetic biodiversity in Brazil were found in the Zoological Record for any of the groups mentioned above. Finally, among the insects, no citation for Hemiptera (true bugs, including bedbugs, stink bugs) was found, although there were many references to studies on Reduviidae (kissing bugs) in the Zoological Record.

Considering plants, there was a noticeable preference for dicots (primarily orchids and cacti), while the greatest gaps were found on bryophytes (moss plants), pteridophytes (ferns), and gymnosperms (pine trees among others). None of these plants were mentioned in any of the data sets (SBG summaries or scientists' answers). Likewise, bibliographical search through the Biological Abstracts was unsuccessful in detecting studies on genetic biodiversity in Brazil for these taxa.

It is difficult to establish *a priori* which of the two data sets best represents the Brazilian scientific community. Each one has its own bias. The contacted scientists are certainly among the best in Brazil at present. Therefore, their responses probably were above the average quality of current work and presumably indicate our current upper limit.

This is indeed what we found when comparing the two sets of data. For instance, in Cytogenetics, among the SBG summaries, the simplest techniques (karyotype or counting chromosomes) were more frequently used than the more sophisticated technique (*in situ* hybridization), while among the answers given by the scientists, the pattern was quite the opposite. Likewise, the majority of the SBG summaries showed descriptive objectives (52%). However, this number declines to 30% in the forms filled out by the scientists. The percentage of works trying to make phylogenetic inferences – rather than merely comparing among species – increased from 36% to 81% in the two data sets respectively. Anyhow, most of the works had already used techniques with some level of sophistication – at least some kind of banding. This overall pattern was present in the other areas.

In the studies with isozymes, in the SBG summaries, the average number of *loci* was 12.1, where 42% of the work used less than ten *loci*. In the answers given by the scientists, the average number was 20 –this was exactly the same number found in a worldwide review by Avise (1994)!– and all reported to use at least ten *loci*.

In Molecular Genetics, 50% of the SBG summaries reported the use of DNA sequencing. This number increased to 74% among the responses of the scientists. With regard to the objectives, in the studies on interspecific variation, among the summaries 83% indicated phylogenetic inference, while among the scientists reports this number was 100%. This indicated that this is probably the field of Genetics using the most modern methods available.

The Quantitative Trait data were, to some extent, heterogeneous. A small portion, 18%, was dedicated to interspecific studies, and 27% had a descriptive nature. In the data from the scientists, seven out of ten responses related to interspecific variation attempted to make phylogenetic inferences. However, no single response from both groups aimed to study QTLs (Quantitative Trait Loci), and only a few were related to genetic variables. Ironically, these are the most modern topics in the field.

The task of studying biodiversity is enormous in any country. We can say that nowhere has been sufficiently studied. It has past only 20 years since the most important tools in genetics have been developed, and only in the last decade they have become accessible. Thus, Brazil is no

exception. There is much to be done for all groups, including the best studied groups. As a matter of fact, they represent an experimental model for the studies with other groups of organisms.

Taking into account the data presented here and the considerations above, we can say Brazil is in a fair to good position considering the most studied taxonomic groups, advanced areas of genetics, and the best prepared research groups. In contrast, there are great gaps in the knowledge on genetic biodiversity in Brazil that can be divided into three aspects: taxa, geographic areas, and field of genetics. Shortly, we can say that the annelids, the echinoderms, the mollusks (cephalopods and Pelecypodae), and the felines are major groups of animals which need to be urgently studied. Of these the most astounding example is related to the felines. The ecological significance of the *onça* (the Brazilian jaguar), and other wild cats, as well as the fact that this is an endangered species and that its populations are almost certainly suffering the effects of genetic drift, make this species a rare opportunity for studying the maintenance of genetic diversity in natural populations. Among the plants, there is a total lack of information for bryophytes, pteridophytes, and gymnosperms. Geographically, the Mid-West is the part of Brazil which most needs research.

Finally, modern genetic analysis of quantitative characteristics, in the context of genetic biodiversity study, is an important gap to be filled, particularly in the quest for the characterization of QTLs, which may represent the synthesis between phenotype and genotype.

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