IUBS SCOPE

Ecosystem Function of Biological Diversity

Edited by

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Biology International

SPECIAL ISSUE 22

Ecosystem Function of Biological Diversity

Summary Report of an IUBS/SCOPE Workshop
held on 29-30 June, 1989, in Washington D.C., U.S.A.

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Special Issue N° 22
BIOLOGY INTERNATIONAL
THE INTERNATIONAL UNION OF BIOLOGICAL SCIENCES
NEWS MAGAZINE

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FOREWORD

Biodiversity is likely to become one of the most crucial issues of environmental sciences, partly because it can be perceived from too many different angles: scientific, ethical and religious, aesthetical, emotional, economic, legal and mandatory, that are not necessarily compatible in their approaches and conclusions.

In addition, nearly all governmental, nongovernmental and private institutions dealing with the environment have quite understandably to deal with processes and issues related to biodiversity. Irrespective of all the efforts of the organizations concerned, this leads almost unavoidably to some misunderstandings and overlaps.

In spite of this, or more likely because of it, biodiversity is also becoming the most exciting and challenging topic of modern science, insofar as the researcher is able to make the problem explicit in terms of well-specified study hypotheses, and as the condition of feasability remains present in the purposes and targets of a given organization or in the mind of a single research worker.

First of all, biodiversity embraces all levels of organization from the molecular unit (and also the chemical and physical ones), to the individual organisms, up to the population, community, ecosystem, landscape and biospheric levels. Disciplines that have currently very few opportunities of operational cooperation (or stand in an unwise and unjustified opposition, as so often happens in the relations between molecular biology and system ecology), could and should be committed in endeavours of mutual interest and reciprocal enrichment.

Secondly, in the light of the forecast global climatic changes that will disrupt the rules of the evolutionary game, at least as far as the scale of time is concerned, little is known of the response of species and populations as regards likely shifts of ecosystems or new fragmentation patterns of landscapes. It is even worth wondering whether the locations of the present day reserves and national parks are the most suitable to ensure biological conservation in a changing environment, or whether they are likely to stand completely out of place. In this case, new systems of reserves should be early designed to permit varied conditions to species for small refugia and larger preservation area, or to apply a new concept of conservation linked to the overall land use practices.

Thirdly, almost nothing is known on the functional role of biodiversity, on the acceptable degree of species redundancy or on the thresholds of irreversibility when decreasing biodiversity, in relation to the very functioning and viability of terrestrial and aquatic ecosystems. It is specifically on this point that a particular emphasis has been given during the joint IUBS/SCOPE Workshop.

In fact, four possible study areas have been proposed to be developed by SCOPE and/or IUBS, as appropriate:

1) The role of biotic and landscape diversity in functional properties and their response to change.

2) Global comparative biogeography.

3) Long-term monitoring of biodiversity as an indicator of change.

4) Accelerated programme for conservation of genetic resources of wild species.

It is evident that the much needed International Convention on Biological Diversity, promoted by UNEP, where enormous scientific and economic interests are involved for both industrialized and developing countries, cannot proceed in line with the vital urgency of the problem, if it is not fed by adequate inputs of scientific and reliable data, particularly on the topics mentioned above.

However, it has to be fully understood by decision makers that these data bases will remain within a range of unavoidable but acceptable uncertainty; this is now "the intrinsic" of a non-linear science in a changing environment.

It is our own scientific and societal responsibility to fill these gaps of knowledge within a limited time horizon that should be compatible with that of the policy decisions and agreements inherent in any international convention.

INTRODUCTION

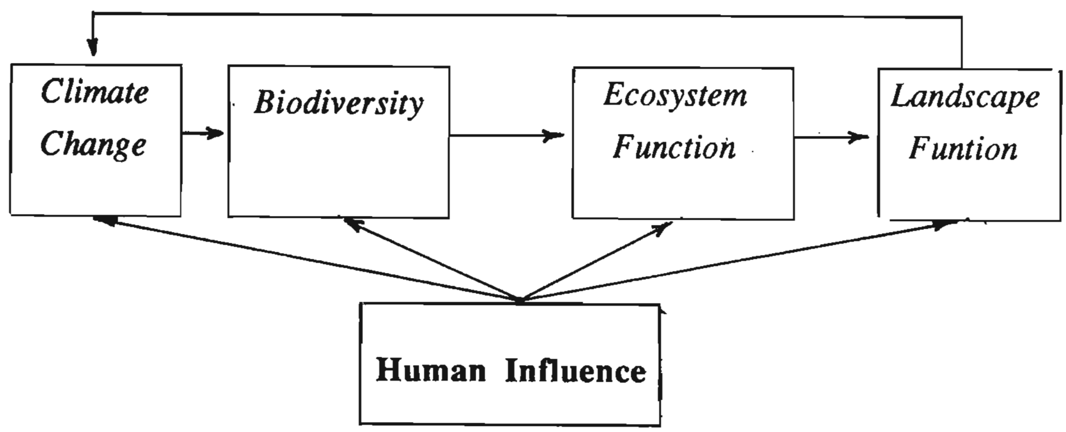
At the present time, the topic of biological diversity is receiving widespread attention in both the scientific and the popular press. Major interest and concern are expressed for the loss of biodiversity from the biosphere (1, 2). Because of accelerating deforestation, particularly in tropical regions, there is a great sense of urgency in devising means to preserve species and natural ecosystems in threatened areas. The arguments that are utilized for species conservation are ethical as well as scientific. The latter include the importance of yet undiscovered species products (drugs of various kinds, for example), and the "services" provided by natural ecosystems (air and water quality, etc.). Unfortunately, many of the ecological arguments that are being made, although most likely correct, are built on an extremely limited data base. Some of the most fundamental assertions are subject to question. For example, rates of deforestation, which we are now able to document fairly precisely with satellite images, are equated with species extinctions. There is good reason to put forward this equation; however, few studies have documented the relationship between forest disruption of varying degrees with loss of species.

On the ecological side, there is little hard evidence to make the linkage between species diversity and ecosystem function. Arguments have been made that with obvious exceptions, individual species do not "count" in ecosystem function, since there is so much redundancy in function among species. Thus the loss of diversity will not be evident in rates of processing of environmental resources. Others, however, give evidence to the overriding influence of certain species in controlling both the structure and functions of ecosystems (dominants and keystone species). There is obviously merit in both arguments for different systems. It is timely to show clearly under what situations one or the other of these possibilities prevails.

Other ecological issues related to the spatial and temporal dimension of diversity need clarification. The integrity and sustainability of ecosystems may be maintained in spite of species deletions up to a point, at which time there will be system degradation. This point may depend however, on prevailing environmental conditions. Episodic extreme events can perturb ecosystem function, and the capacity to resist such events perhaps depends on system diversity, whether high or low. In addition, the ecosystem or landscape role of spatial diversity has not been systematically studied. On a continental scale, we are beginning to see major consequences in the functioning of systems that are not greatly disturbed, due to loss of diversity in distant systems that serve as seasonal habitats for migratory birds. On local scales, the ecosystem importance of hedgerows as reservoirs of diversity in agricultural systems is also now being quantified.

There is no question that not only are deforestation and coastal alterations a threats to biotic diversity, but so is the myriad of landscape usages by human endeavours. We need a better understanding of the ecological significance of these changes and connections (Figure 1), and we need it soon due to the accelerating rates of landscape modification.

Figure 1: The connections



BACKGROUND

In order to address the above questions and to outline an approach that would assist in the clarification of the issues related to understanding the role of biodiversity in the functioning of ecosystems, IUBS and SCOPE, in collaboration with the US/IUBS National Committee, and with financial support from the A.W. Mellon Foundation to SCOPE, organized a small exploratory workshop on *"Ecosystem Function of Biological Diversity"*, on 29-30 June, 1989, at the US National Academy of Sciences, in Washington D.C., USA. Fifteen leading experts from France, Mexico, UK, USA and USSR participated at the meeting.

The IUBS interest in this topic stems from the adoption by the 23rd IUBS General Assembly, in 1988 (3), of a proposal made by the US National Committee of IUBS (4), to launch an international cooperative research programme on *Biological Diversity*. This programme attempts to understand biological diversity in the context of the structure and function of ecosystems. The issue of tropical species diversity has already received substantial interest from the IUBS Decade of the Tropics programme, with the organization of three meetings, and the publication of two special issues of *Biology International* (5,6) devoted to it, the most recent, edited by A. Lugo, was entitled "Diversity of Tropical Species: questions that elude answers".

Also, SCOPE has taken an increasingly greater role in synthesizing information on environmentally related issues involving species, as well as total ecosystems. In the past few years, SCOPE has been engaged in a major study on biological invasions of species and the ecosystem consequences of these invasions. At present, SCOPE is preparing an overview of the potential environmental consequences of bioengineered organisms and is proposing to evaluate possible uses of such organisms in ecosystem management. Finally, SCOPE has a project on ecotones (7), that is very much related to the spatial dimensions of biological diversity.

OBJECTIVES

The main objectives of the workshop were: (1) to identify scientific issues that require international cooperation on both the role of biodiversity in ecosystem function (not to evolve a conservation strategy, but rather to bolster the scientific underpinnings for such a strategy); (2) to address general questions about how knowledge of species and ecosystem diversity can contribute to global ecology; and (3) to investigate how species diversity contributes to system functioning?

Within the framework of the above general objectives, the participants felt that it was essential to deal with biodiversity of plants, animals and microorganisms altogether, at the levels of terrestrial, freshwater and marine systems, and to address more specific questions, for example:

a- How good is our global database on losses or modifications of species, genetic material and ecosystems?

-More specifically, how accurate are the estimates of species losses based on rates of deforestation and other ecosystem alterations?

-What are the consequences of population genetic losses?

-Can remote sensing give us a complete inventory of ecosystem distribution and changes with functional accuracy?

b-What do we know about species losses and/or additions, and impairment of regional processes?

-How is loss of habitat influencing migrating organisms?

-How is habitat fragmentation influencing landscape transfer processes?

-What do we know about the relationship between genetic and species diversity and local ecosystem function? And specifically, how common are keystone species? How common is functional redundancy? Are species or assemblages of species better indicators of system stress than system functional properties? What are the consequences of ecosytem simplification?

c-What role do species *versus* systems play in global system functioning?

-Do dominant species control major fluxes of gases, energy and chemicals?

-How will species *versus* ecosystems respond to global climate change? And what will be the consequences of rapid climate change on ecosystem integrity?

PRELIMINARY REMARKS

On the basis of the presentations and the discussions that followed, the meeting made the following preliminary remarks:

-Documenting species extinctions is not a useful scientific focus if this programme is to fulfill its objectives; however, documenting population and genetic losses due to habitat fragmentation, modification or consolidation is an important focal point.

-The limited evidence to date indicates that, at large scales, biodiversity is not important in carbon, nutrient, and water balance, although it may be important in trace gas fluxes. The reason for this is internal redundancies and compensations.

-The diversity of landscape biotic units, e.g., successional types, is important in landscape functioning. Therefore, there is a need to develop a world strategy for maintaining diverse landscapes. Also, there is a need for more explicit experiments on the role of diversity and fragmentation on system functioning (merging systematic and ecological approaches).

-Species or assemblages of species are more sensitive indicators of environmental change than are ecosystem functional properties, again due to internal compensations.

-Tracking species aggregation changes may help relativize system comparisons.

-Knowledge of biotic and functional diversity in microbial and coastal-marine systems is particulary weak.

-Systematists are becoming an endangered species.

-Scaling of species interactions and ecosystem and landscape functioning, as well as using comparative system approach, are areas that deserve further studies.

POSSIBLE STUDY AREAS

Before identifying priority areas for possible and practical studies, it is very important to recognize gaps and constraints encountered when studying the ecosystem function of biodiversity.

At present, the lack of knowledge of numbers of species within ecosystems and their relationships, as well as the lack of knowledge of extinction and speciation rates represent the major gaps for understanding the ecosystem function of biodiversity. There is also, a serious shortage of studies in biogeography and systematics. On the other hand, in both the short and medium-term, the major constraint is the alarming erosion of those skills and scientific expertise that are necessary to proceed with systematic surveys and biological inventories.

The time dimension is very important, and the tasks to be achieved are extremely urgent. Although this programme is not primarily on species description, we must appreciate that, without a serious and continuous effort to develop systematics research, identification services, training and education in taxonomy and systematics, there is no hope of improving the present situation.

I- THE ROLE OF BIOTIC AND LANDSCAPE DIVERSITY ON FUNCTIONAL PROPERTIES AND THEIR RESPONSE TO CHANGE

Detailed planning is proposed for an experimental programme that would consider structure, diversity, and functional relationships in high priority systems, for example estuaries, tropical forests, and mediterranean ecosystems. Some considerations for these experiments are that they would address functional impacts of additions, substractions, fragmentations, reconstitution, and disturbances on both natural and human-modified systems. The temporal and spatial scales of observations would be appropriate to life spans and ranges of the component species. The behaviour of species, guilds and communities would be monitored and functional properties would be assessed at four levels:

1) demography/biogeography of species;

2) interactions between species, such as mutualisitic interactions or those that are positive for one and negative for the other;

3) sources and sinks for water, minerals and gases; and

4) productivity.

It is anticipated that genetic and species diversity will be very important at small scales of investigation, but they will become less important at larger scales because of buffering and compensations. It is possible that the maintenance of structure, regardless of composition, leads to maintenance of productivity. However, with a reduction in diversity there is a risk of loss of structure and hence a reduction in productivity.

Edge-related changes affecting ecosystem fragments may have dramatic effects on biological diversity of small areas but are probably less significant for larger areas. Comparable scale-related edge effects on ecosystem functional properties are essentially unknown.

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Since disturbance (both natural and human-induced) is a major source of biodiversity in most ecosystems, research should focus on disturbance processes as they affect both biodiversity and ecosystem processes in small spatial scales as well as the integrated effects on large tracts of vegetation. The use of watersheds in experimental manipulations of diversity would make it possible to quantify effects on key ecosystem functional properties such as water and nutrient fluxes.

An integrated programme of study on the role of biodiversity on ecosystem functioning has important practical value in ecosystem management. The information derived from such a programme would also aid in the development of a comparative ecosystem science, which is a crucial component of the study of how the earth system functions.

It is recommended that SCOPE, following the implementation of its projects on "Long-Term Ecological Research" and "Ecosystem Experiments", undertake a study on the design of experiments to be carried out at the ecosystem level, taking into consideration biodiversity changes in both cases of simplification and fragmentation.

Functional Microbial Diversity in Terrestrial Ecosystems

Previous studies on the functioning of undisturbed and non-agricultural terrestrial ecosystems (9, 12) have paid insufficient attention to the role of *microorganisms* in nutrient entrapment, nitrogen fixation, decomposition, soil quality, mutualistic symbioses, and detoxification in both soil and aerial situations.

Further, only about 13% of the world's estimated numbers (Table 1) of microorganisms have been recognized. Also, there could be less redundancy than in other organisms, due to high specialization factors. At present, there is insufficient evidence to state that high proportions are functionally redundant, particularly in the case of species concerned with nitrogen-fixation, mutualistic symbioses, and detoxification.

It is recommended that IUBS, in cooperation with the IUMS, establish and seek funding for an integrated multidisciplinary project in selected well-studied sites in arctic, temperate and tropical biomes, involving algologists, bacteriologists, lichenologists and mycologists to:

-determine the extent of variety and endemism in these organisms;

-quantify their role in vital ecosystem functions;

-provide a basis for the assessment of the relationships between the effects of air pollution, acid rain, and other environmental disturbances on microorganisms and ecosystem function as a whole; and

-conserve in culture collections strains with ecologically important functional characteristics.

Table 1 : Numbers of known species of microorganisms and probable world species totals (D. L. Hawksworth, unpublished)

Group	**Known Species**	**World Species**	**Proportion of Species Known**
Algae	40,000[1]	60,000	67%
Bacteria (Incl. Cyanobacteria)	3,000	30,000	10%
Fungi (Incl. Lichen-forming & Yeasts)	64,000[2]	800,000	8%
Viruses (Incl. Plasmidsand Phages)	5,000[3]	130,000	4%
Protoctists (Incl. Protozoa, Excl. Algae and "Fungal Protoctists")	30,000[4]	100,000	31%
Totals	143,000	1,120,000	13%

1 P.C. Silva (in Hawksworth and Greuter, 1989 (13))

2 Hawksworth *et al.*, 1983 (14)

3 700 plant viruses (Martyn, 1968, 1971), 1300 from insects (Martignoni and Iwai, 1981, 1981); those other hosts estimated (15,16).

4 Wilson, 1988 (1).

Such studies would also result in the discovery, culture, and characterization of species and strains of microorganisms with properties of potential importance in biotechnology and genetic engineering (10,11).

A workshop, to which representatives of all key international scientific bodies concerned with the various groups of microorganisms identified above should be invited, should be convened by IUBS, with the assistance of IUMS, to consider how such a programme might be developed.

II-GLOBAL COMPARATIVE BIOGEOGRAPHY

A "global biogeographic survey" has been a long-sought after goal of many agencies and programmes. Such a survey has often been envisaged as an essential aid to understanding the distribution of life forms over the planet. There can be little question of the scientific importance of evolutionary biogeography or its relevance to the conservation of biodiversity. Nevertheless, we note that both scientific and conservation agencies and programmes have been loathe to undertake this task, due both to its complexity and the variety of often conflicting approaches (5,6).

Five observations may be made concerning this situation. First, biogeographic classifications are necessary for comparing and contrasting ecosystems and for the identification of "representative" research sites and "core" conservation areas. Second, an hierarchical network of observatories is necessary for understanding global change (8) and concurrent losses of biodiversity. Third, a global survey should not be undertaken as an "inventory", that is, a detailed organism-by-organism listing. Difficulties associated with inventories are compounded by uncertainty about the numbers of species on Earth and also about the difference of approach that should be taken between, for example, land and sea (21), due to the magnitude of the task and lack of resources, both human and logistic. Fourth, a description of ecological patterns is necessary for the assessment of habitat loss, against which to measure biodiversity loss. Finally, understanding of species distributions and associations are necessary for interpretations of ecological processes.

There exist a number of biogeographic classifications, biotic surveys, and biodiversity assessments which, though not methodologically consistent, provide an adequate background for a global research programme. Thus, it seems reasonable to take a *comparative* approach in order to establish base-lines against which to assess further changes in biodiversity. This statement is based on the following assumptions:

-Strong connections exist between biodiversity and ecological processes at the landscape level that "constitute a link between global change and changes in species diversity" (4).

-These links occur at different time-space scales from local to regional to global, and are expressive of hierarchical ecosystem, and ecotone concepts (7).

-Species are the best indicators of environmental properties at local scales, and assemblages of species (aggregations, communities) within larger time-space dimensions (see elsewhere in this Report).

-"Indicator assemblages" may offer clues to environmental change on a regional level (e.g., biogeographic provinces)(18).

Methods for depicting global biodiversity, within the context of environmental change, include satellite imagery and interpretation, ordination techniques that describe associations among species as probabilities within landscapes (or seascapes), and studies across ecological gradients. We recognize that the methods used to date and their applications are so diverse that interpretation on a comparative basis can be difficult. There exist, for example, strong differences in methods for various taxa (plants *vs.* animals), among realms (terrestrial *vs.* marine), and among regions (tropical forests *vs.* continental shelves). This is seen as an advantage, for it must be recognized that an integration of techniques across disciplines is mandatory. The coastal zone, where terrestrial, pelagic, benthic, and intertidal systems converge, provides one of the best examples of this point.

We have already noted that a global biogeographic research programme should have one fundamental property, that it should be *comparative*. The outcome should be depictions of pattern at various scales, expressed as a geographic information system with statistical-analytical capabilities. This information system would differ from most previous biogeographies because of its emphasis on relationships between individual species and communities of species to ecological processes-- that is, the goal of understanding "biological diversity in the context of the structure and function of ecosystems" (4). The outcome should facilitate comparisons of relationships among ecosystems. We should be able, for example, to compare:

-small, discontinuous systems of relatively low species richness (lakes, islands, oases);

-large, patchy systems of variable richness (continental shelves, forests);

-relatively even systems of differing time/space properties (pelagic systems, tundra).

There can be little doubt of the potential enormity of a complete global comparative biogeography. Nevertheless, this task is essential, or to put it another way, what might the consequences be of not undertaking it? It is estimated that a regional (biotic province level) classification is achievable in a reasonable period at reasonable cost, by taking full advantage of a number of individual efforts that are already available or underway (e.g., surveys of forest types and function, vegetation modelling, satellite interpretations of habitat change and oceanic productivity patterns, "key" species assessments, etc.).

As a first step, we propose that a workshop be convened in the near future to:

-synthesize available information and methods; and

-establish a research agenda and high priority systems and/or regions for initial emphasis.

The outcome should be the establishment of a systematic basis for comparison. A geographical information system for biological diversity survey, using modern information and communication technologies should be built; this should help to identify high, low or fragile biodiversity areas, and to identify assemblages of species for long-term monitoring. Biodiversity studies should be made on selected species or groups of species, simultaneously with a comparison between the different zones of the world.

In this endeavour, we further propose that close contact be maintained with global change programmes, most particularly the IGBP and long-term national research programmes. There should be emphasis on research at a local scale within representative research laboratories, as well as with those undertaking regional to global modelling. It is recommended that the workshop and leadership of the overall programme reside with the IUBS, in close collaboration with SCOPE.

III- LONG-TERM MONITORING OF BIODIVERSITY AS AN INDICATOR OF CHANGE

Criteria for long-term monitoring of biodiversity are being developed within the framework of the SCOPE on-going projects on "*Long-Term Ecological Research*" and "*Ecosystem Experiments*", due to be completed in the very near future. These criteria on how to use species or assemblages of species for long-term monitoring should be applied within the world protected areas systems, particularly within the "Biosphere Reserves" of Unesco's MAB programme and the Regional Research Centers (RRC), also known as 'geosphere biosphere observatories' of the Global Change Programme (IGBP).

Interests in the science relating to biodiversity and ecosystem function would be well served by use of established and new sites or observatories for long-term or sustained ecological research. Such sites could be used to observe and understand:

-temporal trends in biodiversity and species structure of particular landscapes;

-spatial heterogeneity in biodiversity in respect to landscape fragmentations, patchiness and gradients;

-the relation between species structure, ecosystem function and global change; and

-the relative importance of habitat loss, pollution, invasions, or climate change as mechanisms of extinction.

The sites would also provide locations to focus analyses of biodiversity for a broad set of taxa and to conduct manipulative studies of biodiversity in the context of temporal/spatial variability.

To be useful, these sites should represent major landscapes (or seascapes) of the globe, have institutional commitments to maintain and support integrated ecosystem and systematic research, be used actively by scientists, have some degree of protection or control, and have historic databases, descriptions and inventories.

At each site, some aspects of the biodiversity of the system will be poorly known. Long-term population and community studies would be augmented by functional measurements including productivity, geochemical fluxes and climatic variables, hydrology, and substrata. Experimental manipulations should be conducted in concert with other long-term studies. Experimental manipulations might include additions or exclusions of organisms, nutrients, climatic variables, hydrology and substratum. Controlled system experiments (e.g. "mesocosms") may be useful at some sites.

Discussions of the relationship between development of ecological theory and data on ecosystem diversity first need to be fostered. Travel of systematists among sites and major systematic collections needs to be encouraged.

A number of established terrestrial, lacustrine and coastal sites exist. Long-term marine, large lake and large river sites are urgently needed. For shallow-water marine sites a network of marine stations committed to long-term measurements needs to be established under the auspices of IUBS. Long-Term-Ecological-Research (LTER)-like networks need specifically to address the relationship of biodiversity to other ecosystem measurements. Marine systems need to be incorporated into existing networks.

International Network of Marine Research Stations

As pointed out above, knowledge of marine diversity is particularly important. Marine biodiversity is different in its nature from terrestrial biodiversity and has been generally underestimated (1), and may rival tropical forests in some ecosystems(19,20). Therefore, an IUBS/IABO marine biodiversity programme(22), in cooperation with Unesco/ COMAR, is recommended to include:

-soft sediments of the intertidal zone, the continental shelf and the deep sea;

-coral reef and other coral and hard bottom areas;

-mangroves, sea grass beds, marshes and wetlands;

-coastal lagoons and estuaries.

The aim would be to cover these habitats by a chain of long-term ecosystem observatories which would constitute a databank with information on systematics, population genetics and ecology, ecophysiological properties and toxicology and data on physico-chemical trends on time scales of decades to centuries.

For this purpose, marine research laboratories and coastal marine protected areas provide unique potential because they cover a variety of coastal ecosystems around the entire world's shoreline and near shore areas. The laboratories also possess unique databases sources for variability, resulting from many years of study, and for some marine stations in Europe and the US several decades of observation and recording. Example: the long-term fluctuation of SW English Channel fisheries, and macro-algae and bottom fauna in relation to temperature fluctuations over 70 years (Plymouth-Roscoff). These are excellent data for interpretation of significant changes in marine diversity linked to global climatic changes.

A specific example of long-term monitoring as applied to marine environment would be the establishment of an *International Network of Marine Research Stations (MARS Network)*, which will serve two main purposes:

-to offer a pool of advanced expertise and laboratory facilities for research on biological processes relevent to ecosystem function and species diversity; and

-to provide a base for long-term observational and experimental studies of marine ecosystems, and to develop regional transects explicitly to address spatial and temporal variability across environmental gradients, at the regional scale, and on a time scale of one century.

IV-ACCELERATED PROGRAMME FOR CONSERVATION OF GENETIC RESOURCES OF WILD SPECIES

With few exceptions, most programmes in the conservation of genetic diversity have concentrated on the major crop plant and domesticated animal species, undertaken by FAO, IBPGR and the CGIAR crop germplasm centers.

There is increasing interest in wild relatives of crops. However most wild species are under-represented in germplasm collections (24) .

Regarding plants, the world network of botanic gardens is being organized by the IUCN Botanic Gardens Conservation Secretariat, as a system for germplasm conservation focussing on wild species:

-rare and endangered;
-economically important;
-required for restoration or rehabilitation of ecosystems;
-taxonomically isolated;

and for cultivated species, primitive land races and semi-domesticates (25).

At a national level, the Center for Plant Conservation, Jamaica Plain, covers the conservation of rare and endangered plants of North America through a network of 19 botanic gardens (26).

For microorganisms, culture collections have been seriously neglected as a conservation resource. While the World Federation for Culture Collections (WFCC) has been instrumental in coordinating data on already cultured strains, it does not have the resources to expand the resource base. For animals, some possibilities exist for germplasm and frozen tissue storage.

Integrated Programme

For conservation of biodiversity at the genetic level, it has been assumed that protected areas system (national parks, biosphere reserves, etc.) satisfies our needs. This is an erroneous assumption in that:

-we do not have species inventories for the majority of protected areas and therefore to not know what we are aiming to conserve;

-management systems for most protected areas do not take into account individual species (except in selected cases) let alone genetic diversity;

-assessment of genetic diversity requires detailed eco-geographical surveying for each species.

There is a need, therefore, to:

-assess the effectiveness of the protected area system in covering endangered and seriously depleted species;

-devise appropriate management systems for endangered species and their genetic diversity, bearing in mind that the specific management requirement of a particular species may be incompatible with the conservation of others, e.g., fire as a management tool;

-assess the role of small-scale populations in small-scale reserves in maintaining genetic diversity;

-encourage the creation of a network of *ex situ* germplasm collections (seed bank and field gene banks based on the botanic gardens and culture collection networks) to supplement *in situ* conservation where appropriate, and zoological gardens for animal germplasm;

-focus on priority species of economic importance, needed for restoration and rehabilitation of habitats, or of taxonomic or scientific importance;

-greatly expand the number of "gene sanctuaries" for wild species and crop relatives (27);

-explore the feasibility of conserving primitive landraces (by definition *in situ*) needed to retain the biological diversity of local economic agricultural/livestock/ horticultural systems;

-make a major effort to understand the physiology of recalcitrant seeds (possibly 40,000 species or more) and the large numbers of microorganisms not yet cultured, and ways of overcoming the problems of their conservation and long-term *ex situ* preservation;

-make a major effort to assess the world needs for culture collections of microorganisms (including algae) as a means of conserving germplasm.

This task is to be mainly undertaken by the IUCN and MAB Unesco, in cooperation with the IUBS scientific members (Botanic Gardens, Culture Collections, etc.)

CONTRIBUTORS

The convenors of the meeting were Profs. F. di Castri (France) and H. Mooney (U.S.A). The invited participants that were able to attend the meeting and contribute to this report were as follow: Profs. P. Lasserre (France), J. Sarukhan (Mexico), D.L. Hawksworth and V. H. Heywood (U.K.), J.J. Ewel, J.F. Grassle, T. Lovejoy, J.J. Magnusson, G. Carleton Ray and D. E. Stone (USA), I.S. Reshetnikov (U.S.S.R), Ms. V. Plocq (SCOPE) and Dr. T. Younés (IUBS).

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