LONG-TERM ECOLOGICAL RESEARCH SITES: VALUE AND EXPERIENCE IN THE MAN AND THE BIOSPHERE PROGRAM

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Abstract

UNESCO's Man and the Biosphere Program (MAB) was established in 1971 to promote the integrated use of the natural and social sciences in developing and sustaining harmonious relationships between human activities and the environment at the local, regional, and global levels. It provides an increasingly important framework for intergovernmental and institutional cooperation in addressing interrelated environmental, land use, and socioeconomic problems. MAB's best known project is the international network of biosphere reserves, which includes 269 sites in 70 countries. Each site is intended as a permanent hub for baseline monitoring and comparative research in representative ecosystems, and for developing the knowledge, skills, and attitudes needed for their conservation and rational use, and the mitigation of environmental problems. The paper reviews the characteristics of biosphere reserves, progress in developing their multiple roles, and examples of the concept in practice; and the case for strengthening use of biosphere reserves as bellwethers of environmental contamination and research to determine reliable indicators for characterizing and forecasting environmental health.

Keywords

Biological indicators, biosphere reserves, long-term ecological research, pollution monitoring, Southern Appalachians, toxic substances

INTRODUCTION

The Man and the Biosphere Program (MAB) is probably the best known of UNESCO's science programs, and the international network of biosphere reserves stands its most significant single accomplishment. MAB's basic mission is to promote and facilitate intergovernmental and institutional cooperation in developing the knowledge, skills, attitudes, and trained personnel needed for rational use of ecosystems. Each biosphere reserve is intended to provide a permanent center for carrying out this mission in a particular biogeographical region. MAB now counts 114 participating nations and has sponsored more than 1000 field research and demonstration projects during its first 15 years. Since UNESCO designated the first biosphere reserves in 1976, MAB's global network has expanded to 269 sites in 70 countries, including many of the areas most responsible for developing the theory and practice of ecology.

MAB's organization is structured to facilitate intergovernmental and intersectorial cooperation (UNESCO 1987). The MAB national committees serve as the focal point for the MAB program within the participating member states of UNESCO. Each is responsible for developing its own MAB program and for regional and international cooperation under the MAB aegis. Under MAB guidelines, national committees should include of eminent natural and social scientists from a wide range of disciplines and representing universities, research institutions, and government agencies, which collectively contribute the intellectual, financial, and logistic resources to plan and coordinate the MAB program. In the United States, the National MAB Committee operates as a voluntary partnership consisting of senior scientists representing academia, industry, and seven co-funding agencies (1) which collectively contribute about $1 million (U.S.) to support MAB research, symposia, and administration. The committee is aided by ten MAB project directorates, each responsible for planning and coordinating activities in a particular biome or area of MAB scientific interest, and in day-to-day administration by a secretariat at the Department of State.

At the international level, MAB is supervised, prioritized and coordinated by the International Coordinating Council for Man and the Biosphere (ICC), containing representatives from 30 member states, half of which are elected every two years. United Nations agencies, nongovernmental organizations, and States such as the U.S. which are not members of the Council may send representatives as observers. The International Council of Scientific Unions (ICSU) and the International Union for the Conservation of Nature and Natural Resources (IUCN) are advisory bodies to the Council. The Council is assisted in its work by the MAB Bureau, a small executive committee consisting of the Council's officers which meets regularly to provide substantive guidance, and a Secretariat in UNESCO's Division of Ecological Sciences which provides administrative support for the Council and the MAB Bureau and in coordinating international MAB acti-

vities. The Secretariat has a professional staff of 10, which is augmented by a number of secundments by national MAB committees and consultants enlisted for specific tasks. The current budget from UNESCO and direct national contributions is about $7 million (U.S.).

The regional and global nature of contemporary enviromental issues are increasing the attractiveness of MAB as a framework for scientific cooperation, as evidenced by growing institutional participation and budgets, and the willingness of leading scientists to become involved. The prodigious diversity of international agencies and nongovernmental organizations participating in MAB is due to the relevance of MAB's interdisciplinary problem-oriented approach to the interests of science, conservation, and development sectors. This is increasingly true at the national level, where MAB can provide a neutral framework for cooperation among these sectors in developing the perspective needed to address interrelated environmental, land use, and socioeconomic problems. Biosphere reserves are increasingly recognized as places for demonstrating the value of these partnerships.

MAB RESEARCH PRIORITIES

The MAB program has traditionally been organized to encourage research in particular types of ecosystems or on particular sources of impacts, such as environmental pollutants and the effects of environmental transformations on the behavior, demography, and genetics of human populations. Although national MAB organizations were free to set their own priorities, MAB's international resources have heretofore been directed primarily toward six projects: coastal areas and islands, tropical forests and woodlands, marginal lands, temperate and arctic zones, urban ecosystems, and biosphere reserves. The program evolved in practice as a "loose coordination of heterogeneous packages of national projects," some of which provided valuable theoretical insights into interrelationships between human activities and ecosystems (diCastri 1986). However, for the most part, emphasis focused rather narrowly on characterizing natural processes in the absence of human intervention or on the impacts of particular human activities on natural systems, rather than on man as an integral component of the biosphere at all levels, from local to global. In order to foster MAB's evolution toward a focus on man IN the biosphere, the ICC has adopted four complementary research orientations to provide direction for MAB in the 1990s.

o Ecosystem functioning under different intensities of human impact, with emphasis on local and regional comparisons to improve our ability to distunguish, characterize, and forecast the effects of natural and anthropogenic influences.

o Management and restoration of human-impacted resources, with emphasis on developing ecologically and culturally appropriate types and patterns of sustainable uses

o Human response to environmental stress, including both positive and negative effects of natural hazards, environmental pollutants, pesticides, fertilizers, and other influences on human culture, health and welfare, and the reciprocal influences on the environment.

o Assessment of the relationship between human investments of knowledge, time, and money in fostering social welfare, economic development, and ecological health, with emphasis on developing the scientific basis for concurrently fostering all three at the local, regional, and global levels. The emphasis requires unprecedented and innovative integration of natural and social sciences in developing a sufficient understanding of the coevolution of natural, social, and economic systems, upon which to base enlightened management policies.

The selection and monitoring of indicators of human and ecological health and well-being are relevant to each of these research themes, and can be expected to be given increasing consideration in MAB research designs, particularly in the biosphere reserves.

CHARACTERISTICS AND ROLES OF BIOSPHERE RESERVES

The biosphere reserve concept was influenced strongly by the Conservation of Ecosystems Project of the International Biological Program, and by similar efforts in developed countries to establish protected sites for ecological inventory and monitoring. The successful establishment of "Decade Stations" for the International Hydrological Decade also lent credence to the idea of establishing coordinated global network of protected areas as a territorial and logistic base for MAB (Gilbert and Gregg 1981, Batisse 1986).

When MAB was launched in 1971, developing an international network of biosphere reserves thus became a key element of MAB Project 8, which focuses generally on the conservation of natural areas and the genetic material they contain. The purpose of the project was to help provide the scientific basis for new approaches for conserving biological diversity in light of the increasing ineffectiveness of strict protection approaches, as exemplified by national parks and nature sanctuaries, in dealing with the effects of external land use changes and environmental pollutants, illegal clearing and harvesting of vegetation and wildlife, and other human influences. As the project evolved, biosphere reserves were seen increasingly as the centers for developing and demonstrating these approaches under the vast range of conditions in different countries and biogeographical regions. Today, it is generally recognized that significant

natural areas are part of larger socioeconomic and cultural regions, and that improving human well-being must be part of an effective conservation strategy. A unique purpose of biosphere reserves is to provide a symbolic and practical framework for this integration.

Biosphere reserves are ecologically representative areas designated by UNESCO because of their capability or potential to generate and share useful knowledge for conserving biological diversity within the context of types and patterns of human use and development which are culturally, economically, institutionally, and environmentally appropriate and sustainable.

A biosphere reserve is uniquely defined by three principal roles:

o The Conservation Role, concerning the area's capability and potential to conserve the characteristic ecosystems and natural genetic diversity of a biogeographical region

o The Logistic Role, concerning the area's capability and potential to carry out long-term monitoring, basic and applied field research, and related educational and training activities, and to participate in sharing information through the MAB network,

o The Development Role, concerning the area's capability and potential to demonstrate methods for sustainable uses of ecosystems, and to involve regional agencies, organizations, and local people in planning and management.

The benefits of biosphere reserves to society depend upon the coordinated pursuit of these three roles, which themselves depend upon a growing base of scientific knowledge and technological capability. A few countries, such as Mexico and Honduras, are establishing biosphere reserves as a separate legal category of protected area (Halffter and Ezcurra in press; Tangley 1988). In most countries, legal mandates, management objectives, small size, boundary confuguration. and other factors limit the ability of established national parks, ecological research sites, and other protected areas to carry out all three roles, although many do well in implementing one, or even two of them. For this reason, biosphere reserves in such countries increasingly contain complementary sites under multiple administrators. In these cases, the biosphere reserve can serve as a framework for coordinating monitoring, research, and educational activities on issues of multi-sector, regional, and in some cases global concern. In order to encourage such cooperation, recently designated and proposed biosphere reserves typically bear the names of regions which make sense both ecologically, culturally, and institutionally such as the Pinelands (New Jersey), Lake Torne (Sweden), and the Lake Baikal Region (USSR). Some, such as the Waddensee (The Netherlands and West Germany) and the Champlain Basin (New York, Vermont, and Quebec), are transborder

regions where the biosphere reserve can provide the aegis for international cooperation. Most are expansive areas--the median size of reserves designated since 1984 is about 125,000 ha. (range: 8,017 ha to 7,200,000 ha; Gregg in press), and typically include a representative range of land uses and environmental problems, and, in some cases, sizeable human populations.

UNESCO guidelines organize biosphere reserves into three descriptive zones: the core area, buffer zone, and transition area (UNESCO 1974, 1984, 1987). The core area is a legally protected, and typically large, natural area for conserving the natural ecological processes and biological diversity of one or more of the characteristic ecosystems of the region. It is protected as a regional benchmark of environmental quality. Baseline ecological monitoring is encouraged, and human disturbance is kept to a minimum. Because of their remote locations, secure protection, and scientific mission, core areas of biosphere reserves are often ideal locations for monitoring background levels of anthropogenic pollutants, and a pilot network of sites in the U.S., Chile, and the U.S.S.R. has been established through as part of the Global Environmental Monitoring System of the United Nations Environment Programme (Gwynne 1982; Wiersma and others 1978, 1981, 1986). Each biosphere reserve must contain at least one core area, and many contain multiple core areas.

The buffer zone adjoins, and often surrounds, the core area. It is normally defined by a legal boundary, which usually corresponds to that of a national park or other administrative area. The buffer zone provides for a variety of uses and activities, including in some cases settlements, which are managed compatibly with the protection of the core area. The buffer zone is often a center for manipulative research, demonstration projects, environmental education, and training and extension programs. Like core areas, biosphere reserves often contain many buffer zones.

The transition area, also called the zone of cooperation, surrounds the core area(s) and buffer zone(s). It is typically an open-ended multiple use area where efforts are made to use the knowledge and methods developed in the biosphere reserve for the practical benefit of the surrounding region. Its boundary, which could ultimately extend to the biogeographic limits of the region, is rarely shown on a map, and normally varies in space and time depending on the cooperative programs taking place. It may, however, includes a number of delineated experimental research and demonstration areas which participate actively in the reserve's programs. The transition area contains a full range of human uses and activities characteristic of the region, and often includes seriously degraded ecosystems and large human populations. In long-settled areas such as central Europe, it may encompass landscapes illustrating harmonious patterns of land use. In other regions, especially in developing countries, it may provide important localities for studying the traditional uses of natural ecosystems by indigenous populations, and

applying traditional knowledge to advantage in ecosystem management. It normally is the area affording the greatest opportunities to build a constituency for the biosphere reserve approach through education, extension, and demonstration programs of obvious benefit to local people.

UNESCO's "Action Plan for Biosphere Reserves," approved by the ICC in 1984, has provided an important catalyst for the functional development of biosphere reserves (UNESCO 1984). The plan established nine objectives for the international program, relating to the three basic roles of biosphere reserves, and recommended 35 actions for implementation by MAB national committees and the participating international agencies and organizations. Most of these have been at least partially implemented. In a 1986 MAB survey of the global network, nearly 80% of responding sites reported that they were pursuing seven or more of the nine objectives; with the highest percentages reported for objectives relating to long-term environmental monitoring (98%), conservation of representative natural ecosystems (98%), in situ conservation of genetic resourtces (95%), environmental education and training (92%) and experimental research (91%) (Gregg 1987).

ROLE OF BIOSPHERE RESERVES IN ASSESSING GLOBAL CHANGE

One of the most promising possibilities for the beneficial use of biosphere reserves is in the assessment of global change. Recent advances in ecological modelling, computer and instrumentation technologies make it possible to extrapolate information from many different sites to provide more general perspective on biogeochemical cycling and energy transfers (Dyer and Crossley 1986). Because of their particular role in developing holistic approaches in environmental and ecological sciences, many biosphere reserves are especially well posed to contribute in addressing extraregional and global problems.

In 1986, the International Council of Scientific Unions convened a series of workshops which conceptualized a global scientific effort to improve our understanding of the complex physical, biological, and chemical processes which control macro-scale changes in the Earth's environment. The resulting Geosphere-Biosphere Program, now in the planning stages, could benefit substantially from the MAB network. The principal involvement of MAB is likely to be through the inclusion of selected biosphere reserves as key parts of a hierarchical system of "biosphere observatories" at which basic ecological and biophysical data can be collected on a variety of spatial and temporal scales for studying specific global change phenomena (Dyer, diCastri, and Hansen 1988). One possible component would involve the establishment of satellite-based monitoring of transects, from subregional to continental in scale, across areas believed to be suitable as bellwethers of global change, such as deserts, treelines, forest-grassland borders, and dynamic coastal areas.

In addition to facilitating understanding of global processes, the IGBP data sets may also find important secondary applications in conservation, regional economic development, and environmental assessment, which can be productively explored in biosphere reserves, thus increasing the overall societal benefits of the program.

A CASE STUDY IN THE SOUTHERN APPALACHIAN HIGHLANDS

The U.S. MAB Program has recently selected the Southern Appalachian region in the southeastern U.S. as the site of a pilot project to demonstrate the benefits of the biosphere reserve approach. The region has a long history of involvement in MAB, beginning with designation of the Great Smoky Mountains National Park, administered by the National Park Service, and the Coweeta Hydrological Station, administered by the Forest Service, as biosphere reserves in 1976. The large strictly protected national park, predominantly a core area, is the largest and most biologically diverse reserve in North America's deciduous forest. It has an extensive history of basic research, especially on vegetational structure and succession, but is precluded as a matter of policy from extensive manipulation for research purposes. The Hydrological Station has a complementary history of long-term studies of the effects of experimental manipulations in small watersheds, but lacks a large core area for baseline studies. The two sites were nominally paired in order to strengthen the basis for scientific cooperation. Because of its close ties with the two sites, the Oak Ridge National Environmental Research Park, although not formally designated, was included as a functional part of the association--in effect, as a satellite research site within the transition area. The association of noncontiguous complementary sites came to be known internationally as the "cluster concept" of building functional biosphere reserves (Johnson and Bratton 1978; Johnson, Olson, and Reichle 1977).

Also in 1976, the Southern Appalachian Research and Resource Management Cooperative was established along MAB principles to provide a forum for cooperation among agencies and regional universities in developing perspective for addressing regional environmental and resource management issues. In subsequent years, the park was selected as a pilot site for developing a multimedia background pollutant monitoring program for biosphere reserves (Wiersma, Brown, and Crockett 1978); and the region became a focus of MAB-sponsored research and synthesis on regional ethnobotany, the design of protected areas, the genetic effects of land use and management on small populations, the nitrogen dynamics of natural and managed ecosystems, and the coupling of ecological studies with remote sensing. In recent years, MAB has also been used as an aegis for developing a variety of educational media on regional and global environmental and natural resource issues. In 1984, the region was the site of an international conference on the management of biosphere

reserves.

In 1985, a MAB panel recommended that the existing biosphere reserves and other important conservation and research sites in the region be united to form a Southern Appalachian Biosphere Reserve, which could provide a framework for strengthening the already considerable benefits of regional cooperation. To determine the feasibility of implementing this expanded concept, MAB sponsored a regional study to inform regional institutions and community leaders on MAB goals and benefits, identify environmental and natural resource issues of greatest concern, assess interest in MAB as an aegis for cooperation in developing and sharing perspective for addressing these issues, and recommend a process for institutionalizing cooperation (Gilbert 1986). Among the several major issues identified for special attention were the need to incorporate ecological principles effects of toxic air and waterborne pollutants on ecosystems and human health. The study documented broad-based enthusiasm for using MAB as an aegis for cooperation, and recommended a series of MAB-sponsored workshops to develop the terms of reference for the program and specific projects. This process is well underway, and an interagency agreement involving state and Federal agencies representing conservation, science, and development sectors is expected to be signed in the near future. Among its provisions is the establishment of a coordinating office, which would be supported jointly by participants to assist in program administration and encourage regional, national, and international participation in its various projects. Although the scope of the pilot program has yet to be finalized, a number of elements are either already ongoing or have support among participating agencies. These include: an integrated program for inventorying and monitoring program the region's biological diversity, and for training specialists in these fields; a model plan for managing natural and cultural resource collections, with emphasis on coordinating collections with monitoring and research programs (perhaps including the conceptual basis for developing a pilot environmental specimen banking program, using the guidelines described by Lewis 1987); development of landscape assessment methodologies and coordinated geographic information systems to serve regional research, resource management, and economic development needs; the development of a coordinated strategy for regional participation in studies of global change; and continued development of public educational materials on regional issues and trends.

CHALLENGES AND OPPORTUNITIES

Biosphere reserves offer an unprecedented framework for cooperation among the natural, social, and environmental sciences; among conservation, science, and economic development sectors; and between nations with shared concerns regarding regional and global environmental problems. It has been suggested that, when the international network is mature and the multiple functions of

its federated sites fully developed, it will represent "in microcosm as perfect a model of the biosphere conceived as a cooperative organic whole as it is possible to achieve" (Engel 1985). In providing the basis for sustainable relationships between human societies and particular ecosystems, the reserves collectively offer the promise of a sustainable and cooperative relationship between man and biosphere as a whole.

The symbolism of the biosphere reserve is compelling, and has great potential to motivate people on its behalf. However, MAB must move beyond symbolism to function.

The first challenge is to communicate the practical benefits of an effective biosphere reserve program to its many potential constituencies, so that the development of such a program becomes a source of regional pride and shared commitment.

The second is to institutionalize individual biosphere reserve programs in order to provide the resources needed to carry out the multiple roles of biosphere reserves in particular biogeographical regions. To date, this has been done in only a few cases. Cooperative mechanisms, such as the one being developed in the Southern Appalachians, must become the rule rather than the exception if biosphere reserves are to become proactive frameworks for addressing regional problems.

The detection, monitoring and assessment of toxic substances should be considered in planning the integrated research programs of such institutionalized biosphere reserves, with special emphasis on the baseline monitoring programs of the core areas. In many regions, biosphere reserves may be the sites of choice for such programs because the understanding of ecosystem structure and function enables more realistic selection of target processes and organisms.

The third challenge is to strengthen inter-regional and international cooperation through comparative studies and creative syntheses which provide theoretical and practical knowledge for monitoring and forecasting environmental change and addressing shared environmental problems. There are many promising examples, but the challenge remains enormous. For example, UNESCO has established a multi-national Northern Science Network for coordinating integrated studies in tundra and taiga ecosystems, which has identified a cooperative biosphere reserve program as a major objectives. The U.S. and Canadian MAB programs are developing concepts for a coordinated network of biosphere reserves in coastal and marine areas of the east coast. A pilot multi-media background pollutant monitoring program in biosphere reserves has been initiated as part of the Global Environmental Monitoring System. Comparative ecosystem studies involving biosphere reserves in the U.S. and the Peoples Republic of China are now getting underway. The IGBP may afford a significant role for biosphere reserves in assessing global change.

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