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PROCEEDINGS OF THE
CONFERENCE ON THE MANAGEMENT OF BIOSPHERE RESERVES

Held at the Sheraton Gatlinburg Hotel
Gatlinburg, Tennessee
November 27-29, 1984

Conference Host:

Great Smoky Mountains National Park Biosphere Reserve

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OBJECTIVES AND NATURE OF SCIENTIFIC PROGRAMS IN BIOSPHERE RESERVES

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Abstract.--Three categories of research appropriate to biosphere reserves (reserve-management, natural-baseline, and resource-management) are discussed, as well as the success of the MAB program in stimulating such activities. The potential for collaborative research between paired reserves has not been realized. Technical considerations in research and monitoring programs are also discussed, including the importance of long-term and interdisciplinary studies and of data management.

Key words: baselines, natural areas, long-term research, ecosystem research, data management, inventory.

Research is a key characteristic distinguishing the Biosphere Reserve (BR) Program from many other conservation efforts. As early as the meeting of the Man and the Biosphere (MAB) "Task Force on Criteria and Guidelines for the Choice and Establishment of Biosphere Reserves" in May 1974, it was determined that one of the three purposes or objectives of BR would be "to provide areas for ecological and environmental research." Furthermore, research that would make a contribution to "the theoretical and practical aspects of conservation and natural resources management" was to be a part of the scientific program in addition to research essential to management of the reserves (UNESCO 1974).

The concept of BR as sites for research relevant to resource management and solution of related societal problems has both distinguished the program and made it attractive to many developing nations. Demonstration and educational projects were viewed as a logical extension of this research. Various strategies for integrating the preservation objectives of BR with intensive research programs were proposed, including the use of core areas with strict conservation objectives surrounded by buffer zones where manipulative research and various consumptive land uses could be carried out.

The United States MAB Committee on Project 8 (Biosphere Reserves) developed the concept of paired reserves in the biotic provinces of the United States (Franklin 1977). This concept recognized that it was seldom possible to identify a single area that satisfies all criteria--a large, strictly preserved tract for conservation of a full array of organisms, with a substantial history of research and monitoring and potential for major experimental treatments. The outstanding conservation areas in the United States are typically either national parks or wilderness areas and have limited research histories and potential for experimentation. Many of the outstanding ecological research sites are, on the other hand, U.S. Department of Agriculture Forest Service and Agricultural Research Service Experimental Forests and Ranges and Experiment Stations. Collaborative, MAB-oriented research programs were to be developed between the

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conservation and experimental elements of the BR cluster established in each of the biotic provinces.

Broadly-based research programs have, therefore, been a basic element of the BR program from its initiation. Three important categories of research appropriate to BR-- reserve-management, natural-baseline, and resource-management research--are identified in this paper and illustrated with examples. Successes and falures in achieving the original concept are reviewed. In addition, technical considerations for BR research and monitoring programs, such as the importance of holistic and interdisciplinary projects, long-term commitments, collaboration between BR, data management, and varied logistical support are given. The paper concludes with a discussion of the critical need for agency support in developing the necessary programs.

SCIENTIFIC PROGRAMS IN BIOSPHERE RESERVES

If we look at BR in the context of a regional resource with broad objectives of improving resource management and conservation within a biotic province, three categories of research and monitoring seem apparent. These are: (1) reserve-management research designed to help fulfill the conservation objectives of BR; (2) natural-baseline research designed to provide baseline and other information on natural ecosystems for use either outside or within a BR; and (3) resource-management or land-use research to provide information on management of natural resources for consumptive uses.

Reserve-Management Research

Reserve-management research is related specifically to the management needs of the BR, providing information needed to achieve its conservation objectives. On properties such as the national parks and wilderness, this research usually relates to preserving the diversity and integrity of natural ecosystems and processes, to maintaining populations of specific species, and, in some cases, to restoring natural conditions.

Most of us are familiar with this category of research, which is typically oriented toward problem-solving. There are many examples. Such projects characterize the research programs supported by the National Park Service (U.S. Department of the Interior). Studies of fire ecology (including natural fire regimes and prescribed burning), structure and dynamics of animal and plant populations, and control of introduced species are typical. Such projects have relevance to other ecosystems and resource-management programs in a biotic province. The primary objective of this research, however, is the solution of management problems within the BR.

Natural-Baseline Research

Use of BR for natural baselines can take two major forms: first, surveys, research projects, and monitoring programs to provide information on the status and trends of ecosystem processes, organisms, or elements, including pollutants; and second, as sites for studying ecosystems and landscapes to provide information on natural processes, structures, and especially, linkages between landscapes and ecosystem components.

BR are already undergoing extensive use as ecological baselines. A program for monitoring pollutants in the soil, water, vegetation and atmosphere was developed by

Wiersma and his associates (Wiersma et al. 1978). This program has been implemented at Olympic, Great Smoky Mountains, Glacier, and, on a preliminary basis, Sequoia-Kings Canyon BR, providing information on regional background levels of various organic and inorganic pollutants.

BR are also being used as sites for studying undisturbed ecosystems as well as the ecology of natural populations of specific organisms. The information from such studies contributes to the basic scientific understanding of the natural resources of a biotic province and sometimes proves immediately relevant to resource-management problems.

A study of the alluvial forest ecosystems of the Hoh River Valley in the Olympic BR exemplifies the practical value of such research (Franklin 1981, Starkey et al. 1982). A significant discovery was the importance of tributaries---side channels and terrace streams---to the main river channel; over 90 percent of the fish production, which included several anadromous species, was associated with these habitats that had previously been ignored by forestry and fisheries managers elsewhere in the biotic province. The Hoh River research also provided a natural baseline for fine sediments in spawning gravels; this was applicable as a standard for levels of silt tolerable to spawning anadromous fish in rivers outside the reserve.

Natural-baseline research inevitably serves both the BR and natural resources in the biotic province at large. Any studies that elucidate the current status or trends in pollutants, for example, assist in identifying potential management problems. Similarly, expanded knowledge of ecosystem structure and behavior or of the ecology of species will typically prove useful in the management of a BR, even if it is currently unrelated to a recognized management problem.

Natural-baseline and reserve-management research may overlap substantially. Monitoring of natural populations or ecosystem processes may, for example, be essential parts of reserve-management programs. Problem-oriented baseline programs can contribute significantly to the basic understanding of ecological processes within biotic provinces. The acid precipitation studies being established in several of the national parks provide excellent examples; baseline information essential to park management programs is being obtained simultaneously with knowledge of ecosystem composition, structure, and function.

The large conservation reserves provide some unique and critical research opportunities for their biotic provinces (Franklin 1981). These include the opportunities to study (1) large, natural landscapes and drainage basins, (2) populations of large animals, including ungulates and predators, and (3) large-scale patterns of natural disturbances, as well as (4) serving as baselines for pollutant levels. National parks are superior to wilderness areas under the jurisdiction of the Forest Service, Bureau of Land Management, or the Fish and Wildlife Service for most of these purposes because there are fewer unnatural influences, such as hunting and grazing, within the national parks.

Resource-Management Research

There is a large and continuing need for research on the development and evaluation of methods for consumptive use and management of natural resources within biotic provinces. BR were intended to contribute to such research. Research on management of timber, forage, wildlife and fisheries resources is appropriate, as is rehabilitation of lands adversely affected by extractive processes such as mining. In some biotic provinces, the development of ecologically sound agricultural systems is a logical topic for research programs.

A major element of MAB- related research is the development of technologies that permit resource utilization consistent with the maintenance of the ecological integrity of the biotic province. Strategies for production of multiple goods and services, such as timber and water or agriculture and wildlife, are clearly high priority. Such research typically relies on experimentation, often at the level of watersheds.

Examples of such research are common in the series of experimental forests and ranges and experiment stations that are a part of the U.S. BR system. The research includes studies of the effects of timber management practices on water yields, erosion, and water quality; effects of alternative silvicultural systems on regeneration and growth of various timber types; evaluation of alternative grazing systems for production of domestic livestock and wildlife; and effects of various management practices on the soil properties and long--term productivity of the land.

SUCCESSES AND FAILURES IN THE U.S. BIOSPHERE RESERVE PROGRAM

All three types of research are being done to at least some degree in the U.S. BR, but rarely because of their BR status. Most have viable research programs, as would be expected of areas that are the outstanding natural landscapes (national parks) and the outstanding sites for natural resources experimentation (experimental forests and ranges) in the United States. These programs have expanded during their tenure as BR, but the emphases in the new and expanded programs have generally not reflected their importance as part of this world system or the particular goals of the Bisophere Reserve Program. Nor have they reflected the cluster concept as discussed below.

Several U.S. BR are receiving major research support after successfully competing in the National Science Foundation's Long-Term Ecological Research (LTER) program. In fact, six of eleven selected LTER sites---H. J. Andrews, Central Plains, Coweeta, Jornada, Konza Prairie, and Niwot Ridge---are BR. This provides support for long-term observations and experiments at these sites, contributing to all three categories of research.

As mentioned earlier, several other U.S. BR have been selected as sites in the National Park Service's acid deposition research program. These are currently Olympic, Rocky Mountain, and Sequoia-Kings Canyon. While intended primarily as reserve-management research (identifying threats to and impacts on park resources), this program also produces natural-baseline data for their biotic provinces.

Some collaboration is taking place between core and experimental BR within some of the biotic provinces. Joint studies have been made between Olympic and Cascade Head BR in the Oregonian Province and between H. J. Andrews and Three Sisters BR in the Sierra-Cascade Province. Collaborations are also developing between Coweeta and Great Smoky Mountains BR in the Eastern Forest Province; this cooperation may extend to the Hubbard Brook BR and the Oak Ridge National Environmental Research Park, the latter an outstanding experimental area for which the Department of Energy continues to refuse BR status.

The potential of the paired or cluster concept of the U.S. BR system is largely undeveloped. This is extremely unfortunate for the progress of ecological science in these provinces. Comprehensive research programs have to address both preservation of the natural diversity- genetic, specific, and ecosystem- -and the sustained, balanced use of natural resources. Balanced research and educational efforts similarly must consider jointly the preservation and conservative use of a province's natural resources. Collaborative efforts between research sites and staffs with these complimentary perspectives would contribute significantly to faster advancement toward these goals.

The concept of paired BR was also designed to provide for varied research within a unified research theme. The national parks provide some unique opportunities, as mentioned earlier, including research on essentially natural populations of larger, wide-ranging ungulates and predators. The experimental areas, on the other hand, provide sites where manipulative experiments are possible for both elucidating ecological principles and testing various management concepts. Taken together, a fuller range of research and staff is possible, along with greater overall relevance to human societal objectives and needs.

Overall, the failure to recognize the potential in the BR system appears to be largely institutional. Agencies managing these areas have limited funds and their own priorities for the use of resources. These only occasionally converge with those of the MAB program. The National Park Service has worked hardest at using its resources to meet both internal and MAB objectives. Individual scientists and agencies funding scientific programs probably merit criticism for not making maximum use of BR in programs. It is critical that these sites play their appropriate roles in the developing acid rain research programs. The Department of Energy and the Environmental Protection Agency should extensively utilize BR in their watershed--level research efforts; hopefully, they will.

An obvious problem is the lack of incentives for research collaboration among the BR in a province. Given agency imperatives and budgeting procedures, neither scientists nor research managers are encouraged to cooperate. Some incentives need to be developed to stimulate agencies (on the larger scale) and BR (on the provincial scale) to develop collaborative efforts on issues of common interest.

TECHNICAL CONSIDERATIONS IN RESEARCH AND MONITORING

Points requiring emphasis in the development of research and monitoring programs in BR are the need for:

- Long-term versus short-term studies.
- Holistic versus organismic studies.
- Comparative studies and networking.
- Inventories.
- Data management.
- Facilitation and logistical support of scientific efforts.

These are important considerations in all three types of research as well as in the educational aspects of the BR programs.

Long-Term Perspective

Long-term programs of research and monitoring must be emphasized in BR. It is increasingly apparent that long-term data bases are essential to the resolution of many issues in both applied and basic research and in the identification of developing problems, such as effects of pollutants (Likens 1983). Long-term experiments and monitoring are needed to provide critical tests of hypotheses, measure rates of long-term processes, provide baselines and illustrate trends, and identify and provide information on episodic phenomena.

There are numerous illustrations of the importance of long-term data in ecological and resource-management research. For example, important episodic phenomena, such as freeze damage to saguaro cactus and reproductive patterns of coast redwood or southwestern ponderosa pine, only emerge from such data sets. Important ecosystem phenomena, such as the effects of insect defoliation on nutrient cycles (Swank and others 1981) or impacts on water yields when converting forests from deciduous hardwoods to conifers (Swank and Douglass 1974), can often be seen only in the context of a long-term baseline.

A commitment to long-term research and monitoring also means a significant commitment to field installations. It means long-term experiments involving manipulations of ecosystems along with necessary instrumentation, often in the form of water measuring and sampling facilities. It means permanent sample plots with sufficient marking for their relocation and, often, identification of individual points or organisms. It means establishment and maintenance of exclosures with adequate preinstallation measurements and statistically sound designs. It means commitment to collecting environmental and population baselines in which the initial instrumentation or measurement is only the beginning of an extensive data collection and analysis process. Continuity of measurements is absolutely critical, and it is an institutional responsibility to perpetuate such programs through times of fiscal austerity and personnel changes.

Modern tools, such as remote sensing techniques, can assist in efficient development of these long-term data bases, but they cannot substitute for on-the-ground efforts. There is no easy way to accomplish these goals, nor is there any substitute for thorough knowledge of the natural history of the ecosystems and organisms of interest. The marine monitoring program at Channel Islands BR illustrates the excellent achievements that are possible when thorough biological knowledge is structured in sound statistical designs to achieve well-defined objectives.

Holistic Perspective

Research in BR should emphasize a holistic, ecosystem perspective and the use of interdisciplinary research teams. Most of the important ecological discoveries of the last 15 years have been the result of research projects, such as the International Biological Program, that approached ecosystems in their totality. Examples include recognition of the rapid turnover and high energy requirements of roots and associated below-ground plant parts; the importance of vegetative regrowth in minimizing nutrient losses following disturbance; the importance of canopy-atmosphere interactions in cycling of various substances; the importance of coarse woody debris in forests and streams; and multiple pathways for nitrogen fixation in forest ecosystems.

Holisitic, interdisciplinary research efforts have special significance in BR programs because most of today's important resource-management problems are interdisciplinary. Research on the importance of old-growth forests, effects of acid rain, cumulative effects of manipulation of landscapes, effects of management on long-term site productivity, control of introduced plants, and management of fisheries are simply not susceptible to individual scientific efforts. Furthermore, many of these problems have sociologic and economic dimensions that must be considered along with the ecologic considerations. Scientists associated as agency personnel with a specific BR have a particular responsibility in stimulating research projects and in providing scientific syntheses that have a whole-system perspective.

Comparative Studies and Networking

Collaborations between BR, both within and between provinces, are another important concern. Comparative studies are essential to develop broad patterns in the structure, function, and management responses of ecological systems. Ecosystems exhibit gradients in the types and importance of various processes both between and within a province. MacMahon (1981) illustrates broad patterns of this type in his comparison of successional processes across the spectrum from desert to rain forest. A localized example is the contrast in rates and causes of tree mortality within the coniferous forests of the Pacific Northwest (Franklin et al. 1985). Comparative efforts will clearly be required to place local studies in the regional, national, and world context.

Development of and participation in national and international networks is a systematic approach to comparative research. Several programs of this type have been developed or proposed, including the National Atmospheric Deposition Program, the Global Environmental Monitoring System, and the Integrated Global Background Monitoring Network proposed by Wiersma (1984). Programs of this type are extremely important both in linking BR and in developing broad perspectives on important problems. More limited collaborative experiments or studies are also important, however, as illustrated by a proposal for the exchange of wood samples in a reciprocal study of the rates of wood decay between H. J. Andrews and Coweeta BR.

BR can and should also associate themselves in more loosely structured comparative efforts. Sampling protocols can be established for the collection of meteorological data, design and measurement of permanent sample plots and transects, animal censusing, and monitoring of ecological processes, such as litterfall. Standardized procedures would facilitate comparative analyses and exchange of information between BR. An example is the use of common procedures to establish permanent forest sample plots in the Pacific Northwest and the southern Appalachians.

Inventories

Inventories of the physical and biological resources of a BR are essential to any research and education program. I have not emphasized this particular activity because many U.S. BR are rapidly improving their inventory base. Inventory takes many diverse forms, from geologic and topographic mapping, to periodic aerial photo coverage, to preparation of checklists for individual groups of organisms.

There are a number of documents available that outline the types of inventory data important in BR. Three general comments concern prioritizing, availability, and bootlegging of inventories. Regarding the first, most of us have been involved in preparing lists of parameters for inventory. The listings invariably exceed any forseeable inventory resources. Some types of inventory, such as aerial photo coverage, are so fundamental and have such wide application that they must be given funding priority. Second, inventories must be generally available to scientists and managers. This may be in the form of computerized data sets, or as publications; the printed page still has great value, as illustrated by bibliographic listings (for example, Gaskin and others 1984) and annotated checklists of organisms (for example, Voegtlin 1982). Third, inventories will have to be accomplished as parts of other research or management programs. For example, major inventory needs in BR are often for lower organisms, such as lichens and fungi, and for many groups of invertebrates. Support for surveys of such organisms has been hard to obtain despite their critical importance in many ecosystem processes. Scientists and managers need to link these inventories to more popular programs. Such linkage with functional research or management projects may actually be a preferred approach, as it will help to keep inventories timely and focused.

Geographically-oriented inventories are increasingly important, and many computer-based approaches exist. Some techniques effectively use sample-based models to generate landscape-level ecological data based on topographic maps (Kessel 1979).

Documentation and Data Management

An emphasis on long-term research necessitates a substantial commitment in BR programs to all aspects of data management. This includes thorough documentation of the procedures used in the research and monitoring programs and reduction and archiving of data sets. Data must be available to scientists and managers in a clean form and at the appropriate level of resolution. Financial resources and dedicated personnel are essential; useful guidelines for the management of ecological data sets are available, most recently from the symposium held in South Carolina in November, 1984.

Adequate documentation of locations of field installations and marking of individual plots and organisms is an essential part of the documentation job. It is rarely done adequately.

Facilities and Logistical Support

Research and monitoring programs require support in a variety of forms if they are to develop and prosper. These include facilities for living and working, and logistical support and data bases. Most BR provide some living facilities, but they are rarely adequate. Working facilities should include provision of common scientific instruments, such as balances and drying ovens, as well as space for sample preparation, specimen identification, and other activities. Computer capabilities and working libraries and specimen collections need to be available to scientific groups at a BR. Most scientists and scientific programs will require data sets from the reserve's archives; providing such data quickly and in commonly required formats should be a part of the data management program at each reserve.

Many BR managers do appreciate the important role that logistical support, in its varied forms, plays in attracting and developing major research and monitoring programs. Witness the establishment of the Uplands Field Research Laboratory at

Great Smoky Mountains BR and the rapid development of programs at Sequoia-Kings Canyon BR. All things being equal, and sometimes even unequal, scientists will tend to go where their work is facilitated and appreciated.

CONCLUSIONS

Research and educational programs oriented toward both ecological preservation and resource utilization are objectives of the BR program. Implications include the use of "core" reserves for research and monitoring programs relevant to information needs elsewhere in the biotic province, rather than simply for research needed to manage the core reserve. Also implied is the design of collaborative research programs among BR within a biotic province. Many relevant activities are underway in U.S. BR, but few are a consequence of the MAB program or reserve status. Collaborative efforts among BR clusters are very limited.

Research programs in almost all BR require expansion. These programs should emphasize long-term perspectives; holistic, interdisciplinary approaches; collaborations in comparative studies and in national and international monitoring networks; completion of inventories; and cooperation with other reserves in the biotic province in developing MAB-oriented research and educational programs. Data management should receive increased emphasis. BR managers can strongly encourage appropriate scientific use by providing logistical support and exhibiting positive attitudes.

Agency support is absolutely critical in attaining MAB objectives for BR. Institutional nurturing of such programs through financial and personnel incentives is one example; institutional commitments to the stability of long-term research and monitoring programs is another. Such commitments appear to have been more common early in the history of the Forest Service and Park Service and need to be reaffirmed.

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