The Status of Scientific Activities in United States Biosphere Reserves

by

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INTRODUCTION

Mankind's knowledge and understanding of The Biosphere is often inadequate to deal with the complex ecological decisions that we have to make.* As human activities continue to modify biomes, devastate ecosystems, and increasingly encroach upon the remaining natural areas world-wide, the preservation of representative ecological study-sites becomes crucial. Scientists need both pristine areas in which to observe natural processes and experimenal areas in which new methodologies can be tested and impacts of Man's activities assessed.

In response to increasing world-wide concern over the status of natural resources, the United Nations Educational, Scientific and Cultural Organization (UNESCO) launched the 'Man and the Biosphere Programme' (MAB) in 1971. MAB is an intergovernmental effort which recognizes that international, regional, national, and local, cooperation are essential for the solution of global environmental problems. Designed to provide the basis in natural and social science for wise treatment of The Biosphere, MAB also serves to promote technical training and educate the public (Risser & Cornelison, 1979; Batisse, 1980).

A priority area of emphasis in MAB is the conservation of natural areas and the genetic materials which they contain (MAB Project-8). A principal component of this project is the establishment of a global network of Biosphere Reserves, with a threefold objective: to conserve natural biotic communities, to provide sites for ecological research and monitoring, and to provide facilities for education and training (UNESCO, 1974; Franklin, 1977; Batisse, 1980). As of January 1983, there are 215 Biosphere Reserves in 58 countries. The development of the network from an historical perspective has recently been reviewed by Batisse (1982).

The United States nominated its first Biosphere Reserve sites in 1974. This initial effort has grown into the world's largest domestic or national network of its kind, which, as of January 1983, encompassed 38 sites and totalled nine million hectares. Sixteen of the twenty biogeographic provinces of the US (Udvardy, 1975) are represented, and five of its twelve coastal regions (Gilbert & Gregg, 1981). A description of US Biosphere Reserves as of 1979 can be found in Risser & Cornelison (1979); most of the Reserves are federally administered by the US Forest Service or the National Park Service. (*See* Appendix for list, including name, management emphasis, State, and area, of each of the 38 US Biosphere Reserves.)

The Authors conducted an investigation into the status of scientific activities in all US Biosphere Reserves, in order to examine how successful these reserves have been in meeting the objectives of MAB Project-8. This was in deference to the desire of the US MAB Secretariat to determine the adequacy of available data-bases, the types of research that were being conducted in reserves, the funding and support facilities, and any anthropogenic threats to the Reserves. The purpose of this paper is to present and discuss the results which we obtained, and to identify areas that seem to be in most need of improvement.

METHODS

A questionnaire was developed to elicit information on scientific and related educational activities in all US Biosphere Reserves. These survey forms were mailed to each Biosphere Reserve several weeks prior to telephone contact being made, so enabling the most qualified individual—often the research scientist—to gather necessary data and prepare responses. In July 1981 the responses were recorded *via* telephone by a single surveyor, in an attempt to standardize interpretations and responses.

Activities were listed according to three broad categories: scientific baseline data (30 activities), environmental monitoring (13 activities), and ecological research (39 activities). Major divisions of the survey are listed in Table I.

Adequacy of baseline information (I) referred to the existence and availability of a data base to support the needs of scientists and resource managers. Environmental monitoring (II) was defined as continuous, periodic, or cyclical, measurements of physical and chemical para-

* Hence in major part our (basically educational) World Campaign for The Biosphere, stressed in our Summer issue of last year. Its Declaration, published on pp. 91–2 of that issue, has been widely cited and reprinted, and the Campaign is soon to be taken over and administered by a new world body that is currently being established primarily to foster it.—Ed.

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Table I

Major Topics of the Biosphere Reserve Survey.

I. **Adequacy of baseline information**
   - A. Aerial photography and imagery
   - B. Aquatic ecosystems
   - C. Bibliography
   - D. Data storage and management
   - E. Disturbances
   - F. Fauna
   - G. Flora
   - H. Geologic features
   - I. Macroclimate
   - J. Soils and sediment maps

II. **Environmental monitoring**
   - A. Aerial imagery
   - B. Aquatic ecosystems
   - C. Disturbances
   - D. Geologic features
   - E. Macroclimate
   - F. Participation in national or international monitoring

III. **Ecological research**
   - A. Vegetation and ecosystems
   - B. Wildlife
   - C. Soil ecology

IV. **Effectiveness as a conservation unit**
   - A. Ecosystems
   - B. Specific groups of biota
   - C. Perceived threats

V. **Professional training programmes**

VI. **Public communication programmes**

VII. **Scientific staffing, funding, and facilities.**

meters spanning, or projected to span, five or more years. Ecological research (III) included studies at the population, community, and ecosystem, levels. For each activity, respondents determined whether the activity applied to their Reserve and, if so, assigned to it an adequacy rating. Adequacy was scored by using a scale ranging from 1 to 4, with 4 indicating a comprehensive, up-to-date programme, and 1 indicating inadequate or non-existent data.

An assessment of perceived anthropogenic threats was included in category IV, 'Effectiveness as a conservation unit'. The format for this was similar to that used in a recent National Park Service survey to assess threats to park units (US Department of the Interior, National Park Service, 1980), but included only those threats which had their principal potential impacts on natural ecosystems (rather than visitor experiences). Information was requested on 49 potential threats. Additionally, information was requested on the effectiveness of the Reserve as a conservation unit, on cooperative studies with other reserves or agencies, on public communication programmes, and on logistic support of science activities.

Because the main interest and purpose of the administrative agency has a strong influence on the use of Biosphere Reserves, we decided to group the Reserves into two categories, based on predominant management emphasis, for analysis of the survey data. One group consists of 22 reserves which are *managed primarily for ecosystem conservation*, and include national parks, monuments, and equivalent sites. These sites range from 1,200 to 3,035,200 ha in size, and average 400,000 ha. Research is typically aimed at maintaining or restoring natural ecological conditions, and is observational in nature. The second group consists of 14 sites which are *managed primarily for experimental research* that is oriented towards sustaining or enhancing the productivity of managed ecosystems for human benefit. This research directly addresses the effects of various management strategies on the ecosystems concerned. These experimental Reserves range from 607 to 111,300 ha, and average 18,000 ha in size.

Index ratings for each topic were computed from the adequacy scores and converted to a 100-points scale. Mean values were computed for all activities under each topic for each reserve. The values were then averaged for the whole network for each major topic. Means were obtained for experimental and observational groups of reserves, and then compared by using a 2-samples students' t-test (Bhattacharyya & Johnson, 1977).

Our objectives in this survey were to identify conditions and trends relating to the Biosphere Reserve network as a whole. Individual Reserves sometimes differed widely from the overall network in terms of their strengths and weaknesses, and we have not attempted to assess such differences.

Results

The results of the first section indicate that across all Biosphere Reserves there exists a considerable base of available information. Notable deficiencies lie in aquatic ecosystems, while aerial photography with imagery data and supporting bibliographies comprise the most comprehensive tool. Weather data, flora and fauna check-lists and keys, and topographic maps, were generally rated as adequate. Data on the impact of exotic species, natural disturbance history, and air-quality data, were generally weak. A comparison of experimental and observational ('conservation') groupings of Reserves may be seen in Fig. 1. The experimental Reserves have a significantly

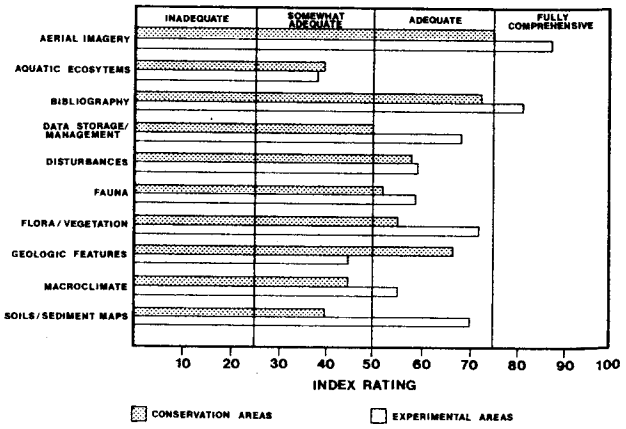

FIG. 1. *Adequacy of baseline information in US Biosphere Reserves.*

higher mean rating in baseline data than the observational Reserves ($p < .05$). Experimental Reserves were rated much higher than observational ones in soil and sediment maps (32 points), flora and vegetation (17), and data storage and management (17).

The degree of environmental monitoring activities was also significantly higher in experimental Reserves ($p < .05$) than in the observational ('conservation') ones. Results are depicted in Fig. 2. Again, aquatic ecosystems

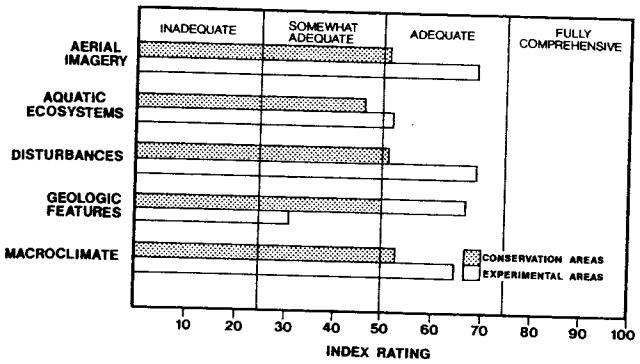

FIG. 2. *Index ratings for long-term environmental monitoring in US Biosphere Reserves.*

are poorly represented. Observational Reserves were rated adequate only in geological features, primarily due to excellent seismic records of the US Geological Survey; this category was weakest for the experimental Reserves. Disturbance, air quality (not shown in Fig. 2), and macroclimate, monitorings are adequate in experimental Reserves.

The level of ecological research across all reserves was quite low compared with monitoring activities. Experimental Reserves engage in more comprehensive ecological research than do observational ('conservation') Reserves, and this difference was highly significant ($p < .005$). However, all scores were relatively lower (*see* Fig. 3) than for other features, with only a few Reserves

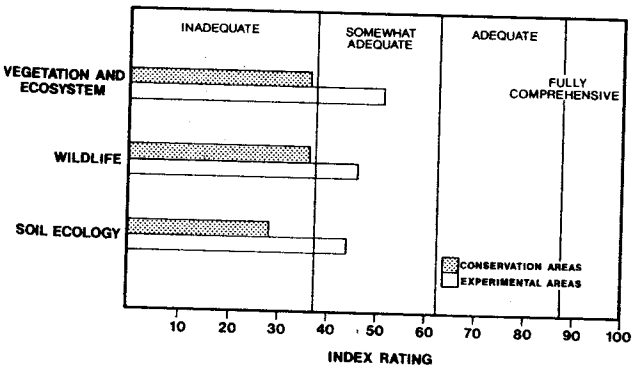

FIG. 3. *Index ratings for ecological research in US Biosphere Reserves.*

having scores in the 'adequate' range. Ratings for individual activities strongly reflected the priority of certain types of research in fulfilling the purposes of the managing agency. Experimental Reserves showed a strong research emphasis on productivity, succession, silviculture, and tropical forest restoration and management, and generally had adequate population-level studies for birds and mammals. Ratings of the observational Reserves were quite low. The highest index rating for the observational Reserves was a 0.50 in fire ecology (not shown in Fig. 3), with the remainder below that; nutrient and carbon cycling (not shown in Fig. 3) and soil ecology studies were all weakly represented.

Table II presents the extent to which each of the surveyed anthropogenic threats was reported as a known or suspected problem in the Biosphere Reserve network. Conservation (observational) areas reported significantly more threats than did the experimental areas ($p < .04$), but are concerned with a greater proportion of their perceived threats than are experimental areas. However, this must be interpreted with caution, as certain threats to conservation areas are part of the focus of research at experimentally oriented Reserves (e.g. clear-cutting and cattle-grazing).

The evaluation of Reserves as conservation units indicated that most of their resources were considered to be effectively protected. Interestingly, experimental-area respondents generally rated their Reserves as more effective in conservation than was the case with respondents from observational areas. From the survey it is impossible to determine whether the lower ratings for observational areas reflected actual conditions or merely a heightened sensitivity to the threats, though we suspect that the latter was the case.

Only four Reserves have no public communication programmes. Communication in the experimental Reserves focuses on contributions of scientific research to improved management pratices and productivity. In the observational ('conservation') Reserves, many of which are national parks, large interpretative programmes are common. However, most of these deal with 'natural history' themes and do not discuss MAB or its goals at all. A visitor to an experimentally-oriented Reserve is four times as likely to hear about MAB than one to an observational Reserve.

Most, but not all, Biosphere Reserves have a reasonable level of basic facilities to support scientists' work, including wet and dry labs. Almost all Reserves are being utilized for professional training, often of graduate students. Furthermore, there has been a steady increase in bachelor's, master's, and doctoral-level graduates in science staffing during the past five years. This improvement has been greater in the conservation areas, although these Reserves still lag behind the exprimental areas at all levels. Average expenditures for science per Biosphere Reserve for the years 1977–81 are shown in Fig. 4. Experimental Reserves spend much more on their science programmes than do observational ('conservation') Reserves ($p < .01$), but the rate of increase during the past five years does not differ significantly between the groups.

Discussion

Throughout the US Biosphere Reserve system, baseline data (such as those of aerial reconnaissance and geological features) are more comprehensive than environmental monitoring data, which in turn are much more extensive than data stemming from ecological

TABLE II

Percentages of Biosphere Reserves Reporting Anthropogenic Threats.

Anthropogenic Threat	Observational ('conservation')	Experimental
Air Pollution		
acid rain	85	69
carbon dioxide	60	50
carbon monoxide	60	62
hydrocarbons	75	62
nitrogenous compounds	70	62
radioactivity	35	44
Exotic Species		
animals	80	38
plants	75	56
unnatural fire	70	75
weather modification	25	12
Operations		
employee ignorance	60	25
poor facilities	60	25
inadequate management plan	55	25
misuse of biocides	30	25
political pressure	65	38
inappropriate research activities	50	44
roads and utilities	80	56
suppression of natural fire	65	62
trails	60	38
Physical Removal of Resources		
archaeological	65	38
fishing	80	50
grazing	65	56
hunting	55	81
logging	25	56
mineral extraction	40	44
oil and gas extraction	25	19
soil erosion	70	75
specimen collecting	70	44
Visitor Physical Impact		
campfires	70	56
erosion	80	50
habitat degradation	50	44
off-road vehicles	55	44
trampling	60	50
wildlife disturbance	85	44
Water Pollution		
chemical pollutants	40	31
deposition	30	38
oil-spills	40	0
radioactivity	20	25
sewage	45	6
toxic material	40	0
unnatural flow	50	31

research. This trend is consistent with that reported by Mack *et al.* (1983) for the National Park Service-administered Biosphere Reserves. Several factors probably account for this difference, one being that costs

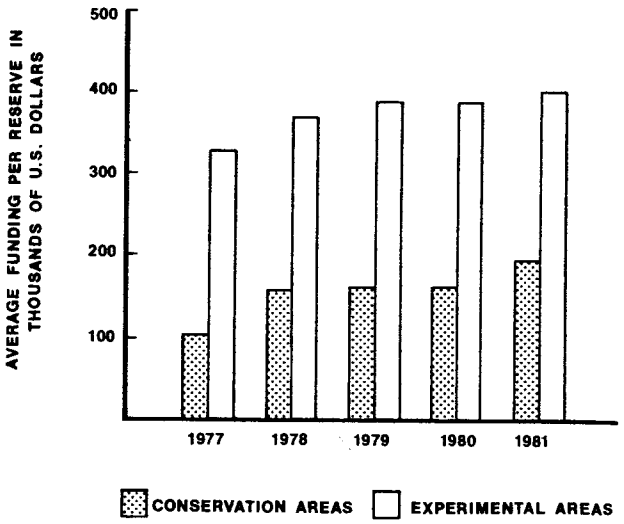

FIG. 4. *Average yearly funding for research in US Biosphere Reserves, 1977–81.*

increase dramatically as research proceeds from descriptive baseline data collection to integrated long-term ecological research. This has served to limit effectively the extent of research occurring in any one Reserve.

Management emphasis is a second limitation; objectives tend to be achieved only in so far as they promote the managing agency's mission.* (It must be remembered that Biosphere Reserve status carries no additional legal protection and entails only voluntary obligations, and that their management is determined by the agency.) But, beyond the administrative orientation of the Reserve, agencies often do not appreciate the necessity of developing long-term data-bases in order to understand major ecosystem processes (White & Bratton, 1980). Too often, research money provided by the parent agency is directed to short-term, immediate projects. In observational ('conservation') Reserves, these may include ascertaining the status of rare and endangered species, monitoring the progress of an exotic species invasion, or monitoring the impacts of visitors in the back-country and developed camp-ground.

Funding for long-term studies is difficult to guarantee, owing to fluctuations in the annual budgets,† and 'manipulative' research is generally not permitted. The experimentally oriented Reserves already have a history of conducting long-term studies on the effects of various management strategies on ecosystems, directed primarily at increasing sustainable yields in forests and on rangelands. Such studies are valuable contributions to our understanding of some of Man's impacts on the environment. Across all the Reserves, however, little if any interdisciplinary research takes places which addresses the large array of feedbacks between Man

* A referee considers that this criticism has 'missed the point', explaining: 'I have had many discussions with American managers of Biosphere Reserves, and they invariably quote the problem as being one of priorities given to maintenance of facilities for visitors rather than to research.'—Ed.

† and (we would comment with a referee), all-too-many other factors.—Ed.

and his environment—including ecological, economic, and social, factors.

Pairing of Conservation and Experimental Sites

The 'classical' Biosphere Reserve, with its core and experimental zones (Batisse, 1982), has been difficult to establish in the US (Fernald *et al.*, 1981; Gregg & Goigel, in press), owing to the practical necessity of designating, as Reserves, sites which already have legal protection. As a result, the US has paired conservation and experimental sites in many biogeographical provinces. Although activities in these two groups of Reserves are often complementary, they are not well integrated.

Most Reserves are, for practical purposes, autonomous study-units. Where integration occurs, it tends to involve only one or two activities. A recent approach involves establishing multiple-site Biosphere Reserves that bear the name of the biogeographic region in which they occur. With the integration of these sites, collaboration among participating institutions should provide the scientific basis for the management of representative ecosystems of the entire region. Given the objectives of the MAB programme (Batisse, 1980), cooperative studies between paired or clustered Reserves are highly desirable—*inter alia* to increase our knowledge of how Man can live in harmony with the environment.

Taken as a whole, the national Biosphere Reserve network represents some of the best-investigated areas in the United States. But, when Reserves are compared according to their management emphasis, experimentally-oriented Reserves consistently score higher than observationally-oriented ones—at least on the basis of the above (mostly scientific) criteria. This probably reflects the longer history and greater intensity of study that is characteristic of most of the experimental sites. Historically, few national parks have employed staff research biologists. If the paired Reserve concept is to be effective, observational ('conservation') Reserves must continue to strengthen their individual research programmes.

Fewer Biosphere Reserves than anticipated are involved in cooperative research or monitoring efforts at the national or international level, although many Reserves are involved in projects at the regional level. The utility and cost-effectiveness of many monitoring activities in the Reserves could be improved through their integration into national and international monitoring systems, and through standardization of methodologies. Batisse (1981) has emphasized that the success of MAB may depend on its ability to carry out projects which provide perspectives on global and broad-regional problems. Biosphere Reserves should play a key role in the furtherance of MAB, but most of the US network are not contributing very effectively in this way. At the very least, improvement of information-flow among Reserves—especially those in ecologically similar regions—is warranted.

Generally speaking, there exists a positive relationship between large scientific staffs and high average index ratings: Reserves with the most such staff (>10) all fall in the top-rated sites (mean rating >60). However, there is considerable variance in this, possibly due to differential use of Reserves by outside investigators. The six best-financed Reserves also received the highest individual ratings. Three Reserves (Channel Islands, Three Sisters Wilderness, and Virgin Islands—*see* APPENDIX) all received their first funding for science programmes between 1977 and 1981.

Some Weaknesses to Strengthen

The survey results identify major deficiencies in important areas of research. Particularly noteworthy are the aquatic ecosystems, wildlife genetics, air pollution impacts, and ethnobotany. Soil ecology, and also newer lines of integrated ecosystem research—such as nutrient cycling and ecosystem modelling—are poorly represented in the conservation areas.*

The lack of an objective basis for assessing and comparing the effectiveness of the Biosphere Reserves as conservation units is indicated by the results. Smaller experimental sites were consistently rated higher than larger observational areas in conserving everything from wide-ranging predatory mammals to airsheds, while they also reported fewer anthropogenic threats. Methodologies need to be developed in this area.

Biosphere Reserves can play an important role in fostering public awareness of environmental problems and the role of science in addressing them. They can serve as focal points for domestic and global cooperation in conservation matters, and help to promote public recognition and support of MAB.† However, the survey results indicate that opportunities are being missed to communicate information and to link Reserves with issues of regional, national, or global, significance. Ninety-seven per cent of the respondents felt that guidance from MAB would be of definitive or potential value in improving their public communication programmes and general usefulness.

Further Needs

The results of this survey point to several weak areas in the scientific activities in US Biosphere Reserves which should be strengthened. The improvement of communications between MAB and individual Reserves, and among Reserves themselves, is desirable. This is necessary for the maintenance of continuity in the MAB programme—in spite of staff transitions at Reserves—and for incorporation of MAB ideals into public education programmes.

Initiation of more cooperative studies, both among Reserves in the same biogeographic provinces and at other geographic levels, should be encouraged by MAB. One critical weakness identified by this study is that most conservation (observational) areas conduct little long-term ecological research, and lag far behind the experimental Reserves in this respect. Conservation areas

* A referee comments on the Biosphere Reserves programme that its 'ultimate objective is to conduct research on how *Homo sapiens* might live in better balance with The Biosphere' and how this is 'too often lost sight of.'—Ed.

† and also of the environmental movement and e.g. World Campaign for The Biosphere (*see* footnote on the opening page of this article).—Ed.

especially must improve their ecological research programmes—this is critical for the paired-reserve concept to be effective and to meet the basic objectives of MAB Project-8.

Across all Biosphere Reserves, efforts should be made to develop research programmes to address major scientific deficiencies which our survey identified—including investigations of aquatic systems, soils, and ecosystem-level units. Finally, increased efforts must be made to initiate studies that include Man as an integral part of the system and at the same time are designed to elucidate ways in which he might live in improved balance with The Biosphere—of which he not only constitutes an integral part and on which he is entirely dependent, but which he is threatening more and more seriously as his numbers and impacts increase.

Acknowledgements

We wish to thank Susan P. Bratton and Frank B. Golley for critically reviewing an earlier stage of the manuscript, and Michael G. Turner for preparing the illustrations. Our research was financed by the US MAB Secretariat; but we wish to emphasize that the opinions expressed in this paper do not necessarily reflect official US National Park Service policy.

Summary

The United States Biosphere Reserve network was begun in 1974, and currently numbers 38 sites. An investigation into the status of scientific activities in US Biosphere Reserves was conducted in 1981 to determine how well the network was meeting the multiple objectives of the Man and the Biosphere Programme. A survey questionnaire was administered to all US Biosphere Reserves, covering the adequacy of available data-bases, the types of research conducted, the perceived anthropogenic threats, funding, support, facilities, and educational programmes. Based on predominant management emphasis, Biosphere Reserves were designated as experimental or observational (i.e. conservational) for the purpose of analysis of the data.

The results of our survey indicate that baseline scientific data, such as aerial photography, bibliographies, weather data, flora and fauna checklists and keys, and topographic maps, are generally available for most of the US Biosphere Reserves; environmental monitoring activities are more comprehensive than ecological research activities, but topic emphasis varies with the management's orientation of the Reserves. Experimentally-oriented Reserves tend to emphasize biological productivity, succession, silviculture, and forest restoration and management, while observationally-oriented Reserves tend towards descriptive studies.

In almost all scientific activities, experimental Reserves were scored higher than observational ('conservation') Reserves in terms of general value; they have also received significantly more funding for scientific research. In all Reserves, most natural resources are considered to be effectively protected. Observational Reserves report a greater number of anthropogenic threats, including air and water pollution, exotic species, operations problems, resource removal, and visitor impacts; but they are addressing a greater proportion of these threats than are experimental Reserves. Most Reserves communicate natural history and other scientific information to the public, but many do not discuss MAB or its goals. Almost all the 38 US Biosphere Reserves are used for professional training and have basic support-facilities for field-work.

Recommendations made for improving the effectiveness of US Biosphere Reserves include: strengthening communications among Reserves within the network; initiating more cooperative studies at all geographic levels; intensifying scientific research in observational ('conservation') Reserves; improving the status of ecological research on aquatic systems and soils, and at the ecosystem level in all Reserves; also designing studies which focus on Man as an integral part of the system and how Mankind might exist in improved concert with The Biosphere. The designation of a multiple-site Biosphere Reserve bearing the name of the biogeographic region in which it occurs, is now being used both to conserve a region's representative ecosystems and to foster cooperation among sites. We believe this is a workable approach and an important first step in implementing these recommendations regionally and, so far as they prove practicable, ultimately globally.

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APPENDIX

United States Biosphere Reserves as of January 1983
(with indication of whether mainly observational [o] or experimental [e])

Biosphere Reserve†	*State, etc.*	*Area (ha)*
Aleutian Islands National Wildlife refuge (o)	Alaska	110,943
Beaver Creek Experimental Watershed (e)	Arizona	113,000
Big Bend National Park (o)	Texas	283,247
Big Thicket National Preserve (o)*	Texas	34,217
Cascade Head Experimental Forest and Scenic Research Area (e)	Oregon	7,051
Central Plains Experimental Range (e)	Colorado	6,210
Channel Islands National Park (o)	California	7,440
Coram Experimental Forest (e)	Montana	3,019
Coweeta Hydrological Laboratory and Experimental Forest (e)	North Carolina	2,185
Denali National Park and Preserve (o)	Alaska	782,000
Desert Experimental Range (e)	Utah	22,513
Everglades National Park (o)	Florida	566,800
Fraser Experimental Forest (e)	Colorado	9,328
Glacier National Park (o)	Montana	410,058
Great Smoky Mountains National Park (o)	Tennessee and North Carolina	208,403
Guanica State Forest (e)*	Puerto Rico	4,000
Haleakala National Park (o)	Hawaii	11,462
Hawaii Volcanoes National Park (o)	Hawaii	92,934
H.J. Andrews Experimental Forest (e)	Oregon	6,100
Hubbard Brook Experimental Forest (e)	New Hampshire	3,075
Isle Royale National Park (o)	Michigan	54,144
Jordana Experimental Range (e)	New Mexico	78,297
Konza Prairie Research Natural Area (o)	Kansas	3,487
Luquillo Experimental Forest (e)	Puerto Rico	11,340
Niwot Ridge	Colorado	1,200
Noatak National Preserve (o)	Alaska	3,035,200
Olympic National Park (o)	Washington	363,379
Organ-pipe Cactus National Monument (o)	Arizona	133,278
Rocky Mountain National Park (o)	Colorado	106,710
San Dimas Experimental Forest (e)	California	6,947
San Joaquin Experimental Range (e)	California	1,832
Sequoia–Kings Canyon National Parks (o)	California	343,000
Stanislaus-Tuolumne Experimental Forest (e)	California	607
Three Sisters Wilderness (o)	Oregon	80,900
University of Michigan Biological Station (o)	Michigan	4,048
Virgin Islands National Park (o)	Virgin Islands	6,130
Virginia Coast Reserve (o)	Virginia	35,000
Yellowstone National Park (o)	Wyoming, Montana & Idaho	898,349

† Management emphasis is indicated by (o) for observationally-oriented Reserves and (e) for experimentally-oriented Reserves.

* Reserve was designated after this study was conducted and was thus not included in the results.