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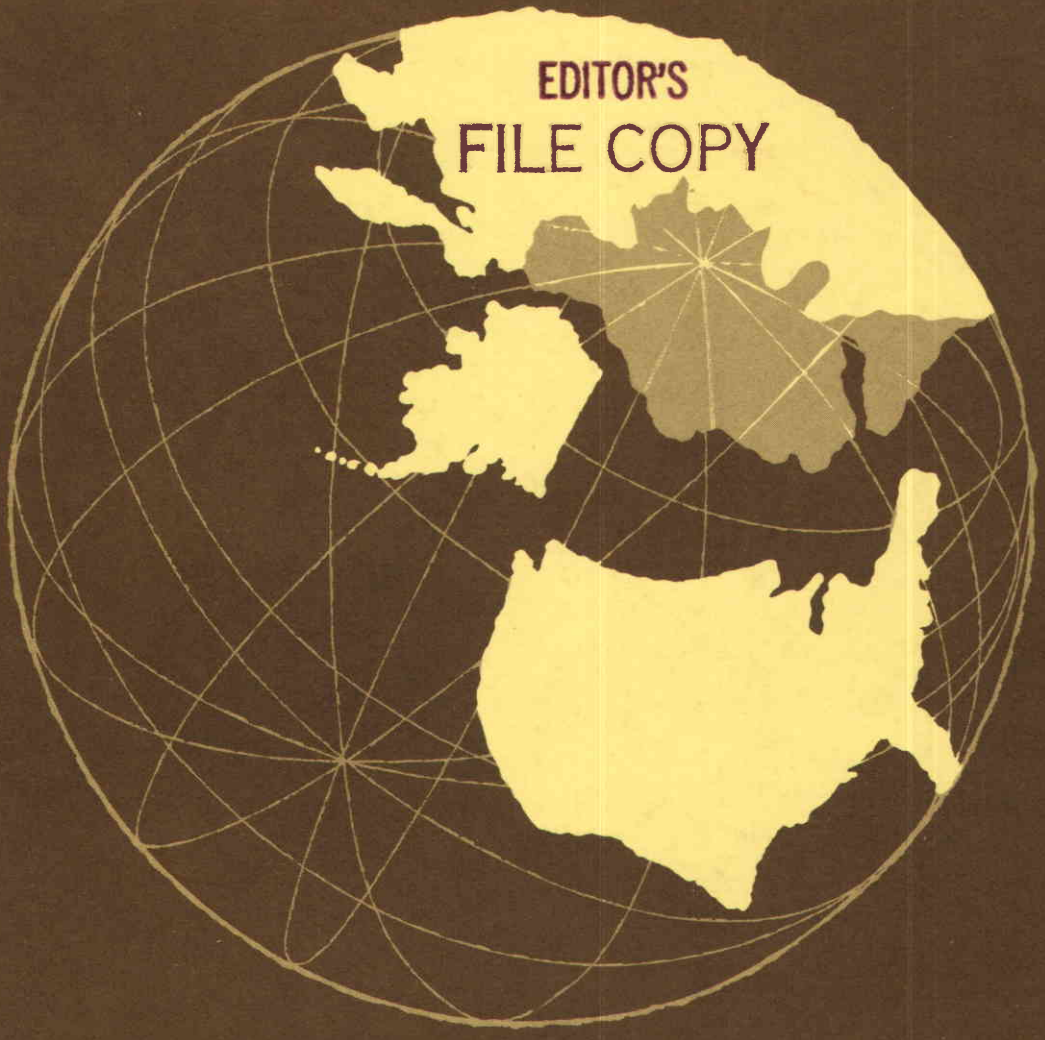

Selection, Management and Utilization of

BIOSPHERE RESERVES

Pacific Northwest Forest and Range Experiment Station
U S. Department of Agriculture Forest Service

ABSTRACT

This publication is directed to the analysis of the selection, management, and utilization of Biosphere Reserves as viewed by scientists from the United States and the Union of Soviet Socialist Republics. Soviet papers focus on types of research and monitoring programs that should be developed on Biosphere Reserves, with emphasis on their use in pollutant monitoring. The nature of the U.S. Biosphere Reserves and their current and potential value for research, education,and biological preservation is considered in the U.S. papers. An additional paper provides an international perspective on U.S. and Soviet collaboration in the field of Biosphere Reserves. Characteristics of Soviet Biosphere Reserves are described in an appendix.

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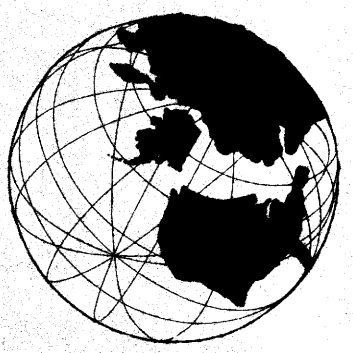

Selection, Management and Utilization of

BIOSPHERE RESERVES

Proceedings of the
United States—Union of Soviet Socialist Republics
Symposium on Biosphere Reserves, Moscow, USSR
May 1976

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PREFACE

In 1974 a project on Biosphere Reserves was established between the United States (U.S.) and Union of Soviet Socialist Republics (U.S.S.R.) under the bilateral agreement on Cooperation in the Field of Environmental Protection. The project was a recognition of the common interest in establishing and using Biosphere Reserves as sites for major ecological research and environmental monitoring programs, as well as for preservation of natural ecosystems and gene pools.

A bilateral meeting of scientists and administrators associated with Biosphere Reserves was held to initiate an exchange of information and viewpoints. This symposium on Biosphere Reserves was hosted by the U.S.S.R. from May 5 to 17, 1976 in Moscow and in several European and central Asian republics. Topics included the selection, scientific utilization, and management of Biosphere Reserves. A report on characteristics of U.S. Biosphere Reserves was reviewed and visits were made to several proposed (and subsequently established) Biosphere Reserves in the U.S.S.R.

This volume is the English-language proceedings of that symposium. A Russian-language version of the proceedings was published in 1977.[1] The contents of both volumes are as identical as we could make them except that an appendix, outlining characteristics of Biosphere Reserves in the U.S.S.R., has been added; these Biosphere Reserves have been established since publication of the Russian-language proceedings.

The Soviet papers are edited from translations provided by the U.S.S.R. with refinement and incorporation of additional material from the Russian-language proceedings. Soviet scientists had limited opportunity to check the final English translations so errors in content are our responsibility as technical editors; for definitive versions of the Soviet papers we refer readers to the Russian-language proceedings. Similarly, literature citations for the Soviet papers were extremely difficult to check; so, contrary to normal procedure, citations for the Soviet papers are generally translated as printed in the Russian-language proceedings and referred to as "References."

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[1] Biosphere Reserves, Works of the First Soviet-American Symposium, Publishing House for Hydrometeorology, Leningrad, U.S.S.R.

The reader will note some general differences in orientation between the U.S. and Soviet papers. The U.S. philosophy has been to identify and establish a large series of Biosphere Reserves which will vary widely in the level of research and environmental monitoring programs. These are viewed as outstanding sites where various independent programs can be located. The potential is limited for a comprehensive program involving essentially identical efforts at all or even a majority of U.S. Biosphere Reserves. Research and monitoring programs are, in effect, to be developed by drawing in and coordinating projects with independent but compatible objectives and funded from various sources. The U.S. papers reflect the constraints of this approach.

The Soviets, on the other hand, view their Biosphere Reserves as sites where comprehensive research and environmental monitoring programs will be carried out. It is their intention that programs at all Biosphere Reserves be comparable in content and intensity and Soviet Biosphere Reserves have been selected with that in mind. For this reason, the Soviet papers strongly address the general research and monitoring activities that can and should be carried out on Biosphere Reserves; they are, in effect, proposing the content of comprehensive, coordinated efforts in their whole set of Biosphere Reserves. This is also the basis for the constraint in designation of Biosphere Reserves; i.e., to establish as Biosphere Reserves only the number and types of sites where major programs are possible. With the intense interest in Biosphere Reserves demonstrated by the U.S.S.R. Academy of Sciences and State Committee for Hydrometeorology and Control of the Natural Environment, both the resources and the will are available to carry out the Soviet design.

Activities have progressed under the bilateral program during the 2-1/2 years that have elapsed since the symposium. Most significant is the recent agreement on a common program for environmental pollutant monitoring program for Soviet and U.S. Biosphere Reserves. This program will be implemented on at least one Biosphere Reserve in each country during 1979 and will provide the basis for future expansion of coordinated data collection and exchange in this and other topics.

JERRY F. FRANKLIN
STANLEY L. KRUGMAN
March 1979

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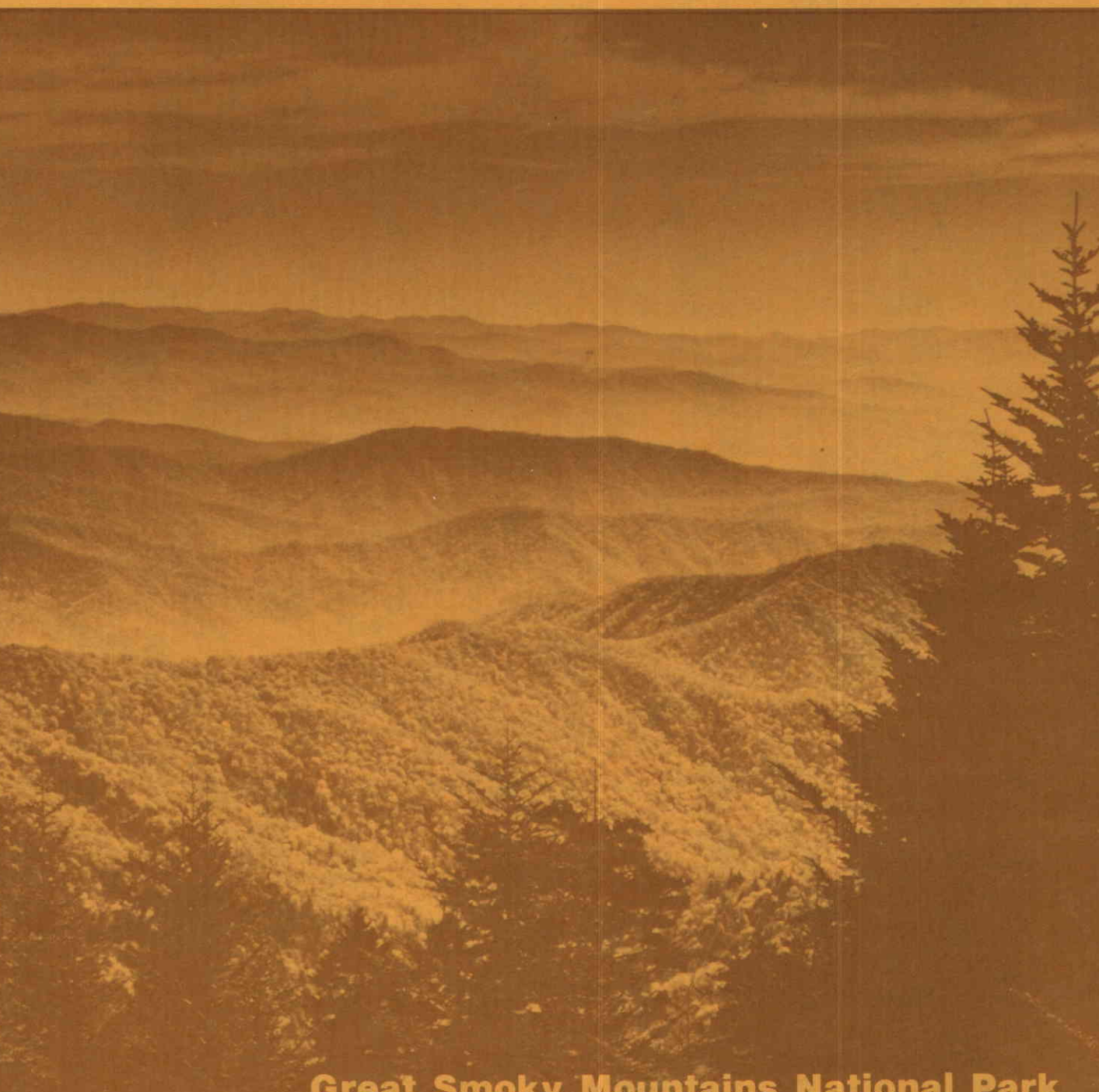
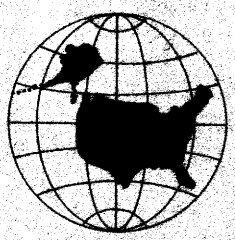


Great Smoky Mountains National Park

Organ Pipe Cactus National Monument



The Conceptual Basis for Selection of U.S. Biosphere Reserves and Features of Established Areas

by

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INTRODUCTION

A bilateral program on Biosphere Reserves must begin with a mutual understanding of the philosophy which is guiding the selection, scientific utilization, preservation, and management of such areas. Such an understanding also requires that scientists in the countries involved know the physical and biological features and research programs on areas designated as Biosphere Reserves. In this way the basis is laid for identifying areas where conservation management programs or research and monitoring programs or both are of mutual interest and where collaboration would be beneficial.

Mutual exposure to the Biosphere Reserve programs in the U.S.S.R. and U.S.A. is a primary purpose of this symposium. I will attempt in this paper to: (1) outline the philosophy of the U.S. Committee for Man and the Biosphere (MAB) Project 8 followed in selecting areas as Biosphere Reserves; and (2) sketch the important features of the 28 U.S. areas that have been designated by UNESCO as Biosphere Reserves.

SELECTION OF U.S. BIOSPHERE RESERVES

Let us begin with an idealized Biosphere Reserve as outlined in the UNESCO documents. What would be among its most important attributes leaving aside for the moment the unique, domesticated, or severely impacted categories of Biosphere Reserves?

1. The area would be a large and diverse segment of the biosphere, in a natural or near-natural condition, which is highly representative of the biological and physical features found in a Biotic Province;

2. The area would have the conservation of biotic diversity, scientific research, and education as its primary land use directives--these directives established and enforced by the Sovereign State in which it is located;

3. The area would be of sufficient size to be viable as a conservation unit and to allow for large-scale replicated experiments without damage to the conservation function; and,

4. The area would have a large established research and monitoring program to provide a good data base and staff for future research and for guidance in the management of the property.

This idealized Biosphere Reserve would be a rare situation in any country. We quickly find that most potential areas lack one or more essential feature, whether it be protective status, level of existing research programs, or overall size.

When we looked at the guidelines for Biosphere Reserves in the United States, two constraints were obvious. First, most public lands are already legally committed to various purposes so that the possibility of creating large new scientific reserves is remote, outside of Alaska. Hence, we needed to consider what could be done using existing reserves dedicated to recreation, conservation, and science.

Second, U.S. participants in MAB Project 8, felt it important to emphasize the research and monitoring aspects of the Biosphere Reserve program. This is not necessarily the worldwide emphasis of MAB Project 8 since a major goal for the Biosphere Reserve program is to stimulate conservation efforts in areas where they presently lag. Where there are already numerous effective conservation programs, as in the U.S.A. and U.S.S.R., research and monitoring is an appropriate distinguishing element for the Biosphere Reserves program. Since the prospect of quickly generating large new research and monitoring efforts was and is limited, we needed to consider utilizing present field "laboratories" which are outstanding sites or centers of excellence for ecological research.

Thus, with these constraints in mind, the U.S. MAB Committee for Project 8 began its examination of potential Biosphere Reserve sites. Initially, we decided to search only for the least disturbed representatives of the major Biotic Provinces as outlined by the International Union for the Conservation of Nature (1974; Udvardy 1975); a few provinces were subdivided to deal with major variants. Our objective was a Biosphere Reserve within each Province or subdivision which would provide an outstanding representation of the biological and physical features and a well established research program.

Two categories of land owned by the U.S. Government are the obvious candidates for Biosphere Reserve status. First, there are the National Parks and Monuments, administered by the National Park Service (U.S. Department of the Interior) and the Wilderness Areas, administered by a variety of agencies under common Congressional guidelines. The National Parks clearly have preservation of the landscape and biota as one of two primary objectives, the other being provision for citizen use and enjoyment. This dichotomy in objectives, roughly describable as preserving nature while simultaneously providing for human recreation, is almost as apparent in the direction for Wilderness management. In either case, the lands are not preserved primarily as scientific "laboratories" although this use is recognized. Preservation of physical and biological features is a primary objective, however, and these tracts represent some of the finest examples of large natural landscapes and, in some Biotic Provinces, the only

significant surviving examples. Research and monitoring programs in the National Parks and in Wilderness Areas, however, have generally been poorly supported. Research has been further limited by the incompatability of many manipulative-type research projects with the primary land-use directives--natural preservation and human enjoyment of the areas.

The second category of relevant areas is the series of reservations which have been established by various agencies as locations for field-oriented research projects and small-scale (pilot) applications of research findings. Examples are the Experimental Forests and Ranges of the USDA Forest Service, some Experiment Stations of the Agricultural Research Service (U.S. Department of Agriculture), and several land reservations under the jurisdiction of the Energy Resources and Development Agency (ERDA). These are sites where scientific use is a primary land-use directive and they are typically under managerial control of research organizations. They are generally of moderate size (e.g., 1 000 to 50 000 ha) and most often are specifically selected as broadly representative of Biotic Provinces or major plant formations. Active research programs have been going on at many of these sites for several decades. A large proportion of the applied, agency-sponsored field research has been and still is centered on these sites. The selection of several of these reservations as intensive study sites by the university scientists who organized U.S.–International Biological Program (IBP) research projects attests to their outstanding character and has resulted in greatly expanded efforts in basic ecological research at these installations. Dr. Risser's paper in this symposium provides further evidence for the continuing and expanding collaboration of basic academic and applied agency scientists on these reservations.

These scientifically-dedicated reserves, which are sometimes referred to as Experimental Ecological Reserves (EER's), are, however, generally not the complete or "ideal" Biosphere Reserve either. Their size, while sufficient for replicated, large-scale field experiments and appropriate control areas, is typically too small to allow for the very large, strictly preserved tracts of the sort necessary for protecting a sample of the organic diversity within a Biotic Province. Conversely, application of a strict "hands-off" policy would seriously limit their usefulness as experimental sites.

The U.S. MAB Committee for Project 8 decided that the best solution to this dilemma was a matching of selected large, natural reserves with nearby research-rich, experimentally oriented reservations. Together a pair of areas would fulfill the functions or concept of a Biosphere Reserve in each Biotic Province.

This, then, was the philosophical basis on which the initial selections of Biosphere Reserve candidate areas were made (fig. 1), (table 1). All of the sites selected share the common feature of being an outstanding example of the physical and biological features of the Biotic Province in which they are located. In general, where there are pairs of areas, one is the best of the natural or conservation-oriented reserves within the Province, while the other represents the outstanding center for field research and experimentation

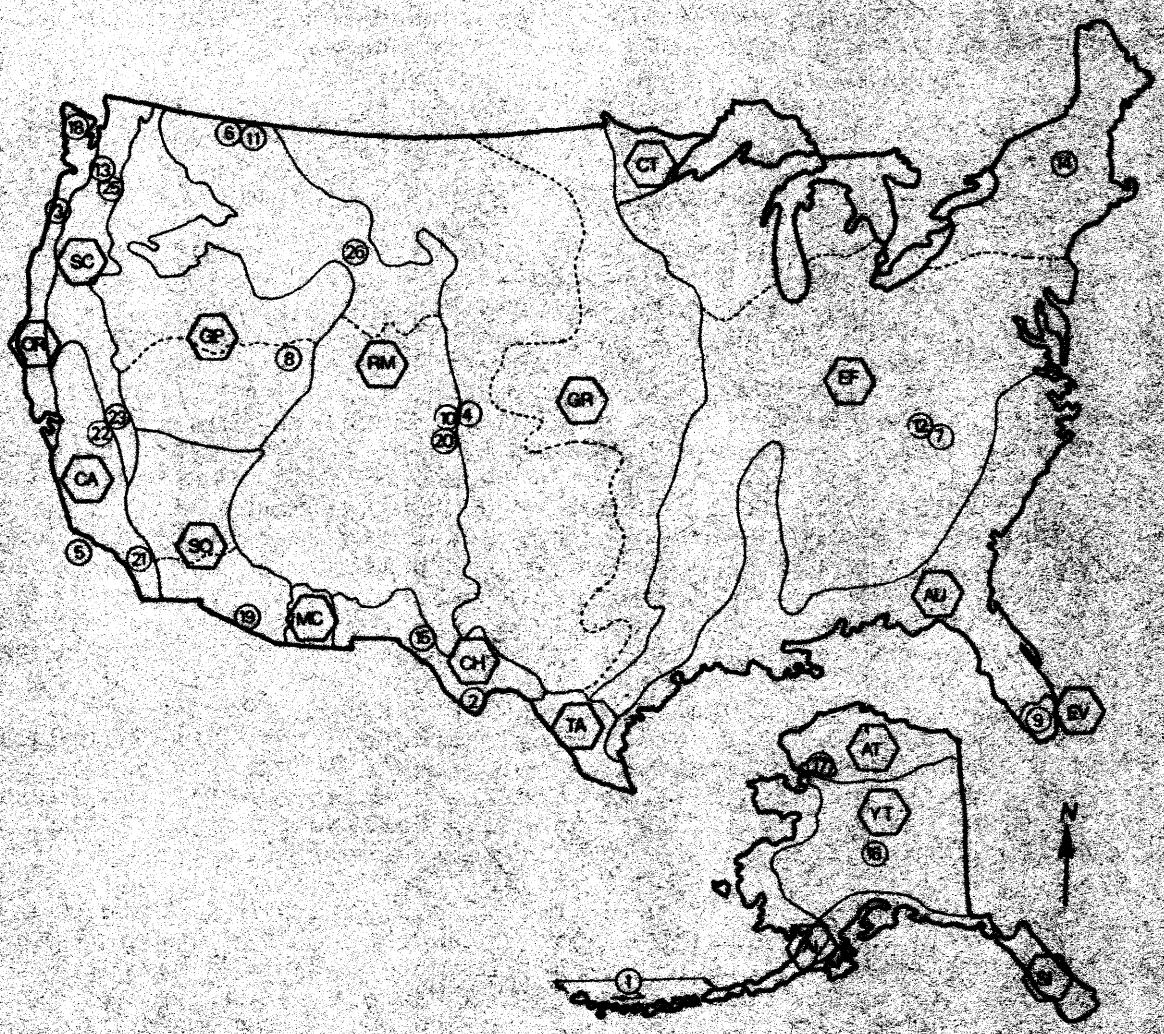

Figure 1.—Location of established biosphere reserves and biotic provinces in the continental United States (including Alaska); province subdivisions are indicated by dotted lines. Alphabetic designations refer to biotic provinces: *AI*, Aleutian Islands; *AT*, Alaskan Tundra; *AU*, Austroriparian; *CA*, Californian; *CH*, Chihuahuan; *CT*, Canadian Taiga; *ER*, Eastern Forest; *EV*, Everglades; *GB*, Great Basin; *GR*, Grasslands; *MC*, Madrean-Cordilleran; *OR*, Oregonian; *RM*, Rocky Mountains; *SC*, Sierra-Cascade; *SI*, Sitkan; *SO*, Sonoran; *TA*, Tamaulipan; *YT*, Yukon Tundra. Numbered areas refer to biosphere reserves: 1, Aleutian Islands National Wildlife Refuge; 2, Big Bend National Park; 3, Cascade Head Experimental Forest; 4, Central Plains Experiment Station; 5, Channel Islands National Monument; 6, Coram Experimental Forest; 7, Coweeta Experimental Forest; 8, Desert Experimental Range; 9, Everglades National Park; 10, Fraser Experimental Forest; 11, Glacier National Park; 12, Great Smoky Mountains National Park; 13, H. J. Andrews Experimental Forest; 14, Hubbard Brook Experimental Forest; 15, Jornada Experimental Range; 16, Mount McKinley National Park; 17, Noatak National Arctic Range; 18, Olympic National Park; 19, Organ Pipe Cactus National Monument; 20, Rocky Mountain National Park; 21, San Dimas Experimental Forest; 22, San Joaquin Experimental Range; 23, Sequoia-Kings Canyon National Parks; 24, Stanislaus Experimental Forest; 25, Three Sisters Wilderness; 26, Yellowstone National Park.

Table 1--Distribution by biotic provinces and characteristics of established Biosphere Reserves in the United States and its territories

Biotic province or subdivision[1]	Name and location or area	Outstanding features	Size (ha)	Administering agency	Orientation[2]
Alaska Tundra	Noatack National Arctic Range, Alaska	Major arctic river basin (tundra ecosystems)	3 000 000	Department of the Interior, Bureau of Land Management	C
Aleutian Islands	Aleutian Island National Wildlife Refuge, Alaska	Includes essentially all the Aleutian Island chain	1 100 000	Department of the Interior, Fish and Wildlife Service	CE
Austroriparian[3]					
Californian	Channel Islands National Monument, California	Two islands (453 ha) and adjacent ocean; abundance of endemic biota and marine fauna	7 440	Department of the Interior, National Park Service	C
	San Dimas Experimental Forest, California	Typical chaparral ecosystem; history of ecological and watershed research	6 947	Department of Agriculture Forest Service	E
	San Joaquin Experimental Range, California	California Central Valley annual grassland and oak savanna; history of ecological and range management research	1 861	Department of Agriculture, Forest Service	E
Chihuahuan	Big Bend National Park, Texas	Representative desert mountain and lowland ecosystems	286 600	Department of the Interior, National Park Service	C
	Jornada Experimental Range, New Mexico	Typical desert grasslands; history of ecological and range management research	77 000	Department of Agriculture, Agricultural Research Service	E
Eastern forest[3] (south)	Coweeta Experimental Forest, North Carolina	Typical southern Appalachian mixed hardwood forest; history of watershed and ecological research	2 300	Department of Agriculture, Forest Service	E
	Great Smoky Mountains National Park, Tennessee and North Carolina	Appalachian mountainscape with rich biotic diversity including hardwood and spruce-fir forests; history of ecological and biogeographical research	207 500	Department of Interior, National Park Service	C
Eastern forest (northeast)	Hubbard Brook Experimental Forest, New Hampshire	Typical northern Appalachian mountain drainage of mixed hardwoods and spruce; history of ecosystem and watershed research	3 075	Department of Agriculture, Forest Service	
Eastern forest[4] (northcentral)					
Everglades	Everglades National Park, Florida	Subtropical forest, mangrove, swamp, and marshland and near-shore marine ecosystems; rich biota; substantial ecological research including experimental manipulations	566 800	Department of the Interior, National Park Service.	CE
Grasslands (short-grass)	Central Plains Experiment Station, Colorado	Typical short-grass prairie ecosystems; history of ecological and range management research	6 280	Department of Agriculture, Agricultural Research Service	E
Grasslands (true prairie)					
Great Basin[3] (north)					
Great Basin (south)	Desert Experimental Range, Utah	Typical salt desert shrub (salt bush-greasewood) and juniper-pinyon pine ecosystems; history of ecological and range management research	22 513	Department of Agriculture, Forest Service	E
Greater Antillean	Luquillo Experimental Forest, Peurto Rick	Tropical rain forest, montane thicket, palm and dwarf forest ecosystems; rich biota; history of ecological and silvicultural research	11 300	Department of Agriculture, Forest Service	EC
Hawaiian[4]					
Lesser Antillean	Virgin Islands National Park, Virgin Islands	Tropical ecosystems including near-shore marine areas	6 130	Department of the Interior, National Park Service	C
Micronesian[4]					

(See following page)

Table 1--Distribution by biotic provinces and characteristics of established Biosphere Reserves in the United States and its territories--Continued

Biotic province or subdivision[1/]	Name and location or area	Outstanding features	Size (ha)	Administering agency	Orientation[2/]
Oregonian	Cascade Head Experimental Forest and Scenic-Research Area, Oregon	Coastal Sitka-spruce-western hemlock forests and estuary; history of ecological and silvicultural research	7 051	Department of Agriculture, Forest Service	E
	Olympic National Park Washington	Coastal mountain system with dense coniferous forest, coastal and alpine ecosystems; abundant glaciers and large elk herds	362 850	Department of the Interior, National Park Service	C
Rocky Mountain (north)	Coram Experimental Forest, Montana	Typical montane mixed-conifer forests of Douglas-fir, western larch, and lodgepole pine; history of ecological and silvicultural research	2 984	Department of Agriculture, Forest Service	E
	Glacier National Park, Montana	Broad range of typical mountain landscapes and ecosystems from prairie margin to alpine	410 000	Department of the Interior, National Park Service	C
	Yellowstone National Park, Wyoming, Idaho, and Montana	Unique area with abundant thermal phenomena and larger mammals; history of ecological research	900 000	Department of the Interior, National Park Service	C
Rocky Mountain (south)	Fraser Experimental Forest, Colorado	Subalpine forests of subalpine fir, Engelmann spruce, and lodgepole pine and alpine tundra; history of ecological and watershed research	9 500	Department of Agriculture Forest Service	E
	Rocky Mountain National Park, Colorado	Typical montane and subalpine forest ecosystems and alpine tundra	106 160	Department of the Interior, National Park Service	C
Sierra-Cascade (north)	H. J. Andrews Experimental Forest, Oregon	Dense coniferous forest ecosystems of Douglas-fir, western hemlock, cedars, and true firs; history of ecosystem and watershed research	6 050	Department of Agriculture, Forest Service	E
	Three Sisters Wilderness, Oregon	Dense montane and subalpine forests of Douglas-fir, hemlocks, and true firs, alpine ecosystems, and recent volcanic formations	80 980	Department of Agriculture, Forest Service	C
Sierra-Cascade (south)	Sequoia-Kings Canyon National Parks, California	Representative Sierran mixed-conifer forests (sugar pine, incense-cedar, true firs); subalpine and alpine ecosystems	341 754	Department of the Interior, National Park Service	C
	Stanislaus Experimental Forest, California	Representative Sierran mixed-conifer forests; history of ecological and silvicultural research	683	Department of Agriculture, Forest Service	E
Sitkan[4/]					
Sonoran (typical)	Organ Pipe Cactus National Monument, Arizona	Desert ecosystems including rich diversity of cacti	134 000	Department of the Interior, National Park Service	C
Sonoran (Mojave)[4/]					
Yukon taiga	Mt. McKinley National Park, Alaska	Representative tundra and taiga ecosystems including large ungulate and predator components	784 980	Department of the Interior, National Park Service	C

1/ Biotic provinces are as defined in "A classification of the Biogeographical Provinces of the World" (Michael D. F. Udvardy, International Union for Conservation of Nature Occasional Paper 18, 48 p., 1975) with additional subdivisions by U.S. MAB Committee for Project 8.

2/ "Orientation" refers to whether the area is oriented primarily toward conservation (C) or experimental research (E).

3/ The Savannah River (SC), Oak Ridge (TE), and Arid Lands Ecology (WA) Reservations of the Energy Research and Development Administration (ERDA) have been proposed for sites in the Austroriparian, Eastern Forest (South) and Great Basin (North) Biotic Provinces, respectively. ERDA has, thus far, not designated any portions of these sites as Biosphere Reserves because of concerns over agency prerogatives.

4/ Good candidates for Biosphere Reserves have been identified, but a final selection has not been made.

in that Province. It is planned that the paired conservation and experimentally oriented Biosphere Reserve will develop collaborative programs to fulfill the conservation, research, and educational goals of the MAB Program. Examples of appropriate collaborations and linkages are apparent in other symposium papers by Evison and by Johnson, Olson, and Reichle.

There are some deviations from the philosophical framework I outlined above. First, the U.S. has obviously not nominated candidate Biosphere Reserves within all of the Biotic Provinces. In some Provinces, selection of the superlative site will require careful, comparative evaluation of alternative tracts. In other Provinces, candidates have been selected but the concurrence of the responsible agency in nominating the site has not been forthcoming. In a few Provinces, a single area can or of necessity will have to fulfill all functions of a Biosphere Reserve.

Alaska presents the United States with a special opportunity since here it will be possible to create new reserves of sufficient size and management flexibility to fulfill all Biosphere Reserve functions. Selection of candidates is proceeding slowly, however, due to uncertainties as to the ultimate allocation of lands among various ownerships and Federal agencies. There is also the added difficulty of initiating major new research programs in these remote and poorly known regions. Nevertheless, Alaska does provide outstanding opportunities for establishing Biosphere Reserves in the future.

CHARACTERISTICS OF U.S. BIOSPHERE RESERVES

The remainder of my paper is devoted to summaries of the important natural features and research programs on Biosphere Reserves in the United States. It is intended to introduce the audience to the sites thereby helping Soviet and other scientists to identify U.S. Biosphere Reserves which are of special interest. The U.S. MAB Committee for Project 8 has identified three additional sites with outstanding potential as Biosphere Reserves and requested their designation but the responsible agency has not yet agreed to their nomination; these are the Savannah River and Oak Ridge Reservations and Arid Lands Ecology Reserve of the Energy Resources and Development Agency.

Aleutian Islands National Wildlife Refuge

This 1 100 000-ha reserve includes all but seven of the islands within the Aleutian Island chain (lat. 52° 40'N long. 177°N 30'W). There are a total of nearly 70 named islands. This area is administered by the Fish and Wildlife Service (USDI). The climate is cool, foggy, and rainy; and the topography is mostly mountainous with elevations ranging up to 2 700 m. There are many lakes and streams and thousands of kilometers of rugged coastline. The vegetation is primarily tundra with *Salix* and *Alnus* shrub communities. Offshore waters support extensive kelp beds.

The fauna is rich and includes both Asiatic and North American elements. The sea otter (*Enhydra lutris*) now numbers nearly 20,000. The northern sea lion (*Eumetopias jubata*) is common. Unimak Island has a population of Alaskan brown bear, (*Ursus arctos*), over 1,000 caribou (*Rangifer arcticus*), and many wolves (*Canis lupis*) and wolverines (*Gulo luscus*). More than 2,000 wild reindeer (*Rangifer tarandus*) live on Atka Island. Small mammals, except for the tundra vole (*Clethrionomys rutilus*) and Norway rat (*Rattus norvegicus*) (introduced), are rare west of Unimak Island. Streams are heavily used by spawning salmon.

Colonial sea birds are the most conspicuous faunal element. The vast rookeries include fulmars, (*Fulmarus glacialis*), two species of petrels (*Oceanodroma* spp.), three species of cormorants (*Phalacrocorax* spp.), black-legged kittiwakes (*Rissa tridactyla*), glaucous-winged gulls (*Larus glaucescens*), guillemots (*Cepphus columba*), murres (*Uria* spp.), murrelets (*Synthliboramphus antiquus*), six species of auklets (*Aethia* spp., *Cerorhinca* sp., *Cyclorrhynchus* sp., *Ptychoramphus* sp.), two species of puffins (*Fratercula corniculata* and *Lunda cirrhata*), and three species of loon (*Gavia* spp.). Large numbers of waterfowl winter in and among the islands and others nest there during the summer. The Aleutian Canadian goose (*Branta canadensis leucopareia*) exists only on Buldir Island. Bald eagles (*Haliaeetus leucocephalus*) and falcons (*Falco* spp.) are common. A number of Asiatic birds also have been found. Substantial faunal and anthropologic research has been conducted on the islands with Amchitka Island being the most comprehensively studied.

Big Bend National Park

This 286 600 ha reserve was established in 1944 along the Rio Grande River in southwestern Texas (lat. 29° 15'N long. 103° 15'W). It is administered by the National Park Service. There are many deep canyons and the entire Chisos Mountain range is in this rugged region of limestone and igneous extrusive rocks. Elevations range from 540 to 2 350 m. Average rainfall in the lowlands is 33.5 cm of which most occurs from May through October.

The area is an outstanding example of the Chihuahuan Desert Biotic Province. Major ecosystem types include shrub, succulent grass, desert, chaparral, evergreen and evergreen-deciduous woodland, and river flood-plain-arroyo (Wauer 1973, Whitson 1974). A lower desert formation is dominated by *Larrea tridentata*, *Flourensia cernua* and locally *Prosopis glandulosa* and *Atriplex canescens*. This formation grades into mid-elevation desert formation dominated by succulents or semi-succulents (commonly *Agave lecheguilla*, *Opuntia engelmannii*, *Hechtia scariosa*, *Euphorbia antisyphilitica*, *Jatropha dioica*, and *Dasylirion leiophyllum*) with local occurrences of shrubs (e.g., *Rhus virens*, *Acacia constricta*, *Ephedra* sp., and *Fouquieria splendens*) and/or grasses (e.g., *Bouteloua breviseta* and *B. eriopoda*). Chapparral is found at higher elevations and is characterized by a shrub and tree canopy usually less than 1.5 m tall; *Quercus* spp., *Cercocarpus montanus*, *Viguiera stenoloba*, and *Rhus aromatica* are characteristic. Evergreen and mixed evergreen-deciduous woodlands are generally found above 1 500 m and consist of widely spaced trees up to 8 m tall.

Typical species are *Quercus grisea*, *Q. emoryi*, *Q. gravesii*, *Juniperus pinchotii*, and *J. deppeana*.

Distinctive vertebrates include the javelina (*Pecari angulatus*), yellow-throated packrat (*Sigmodon ochrognathus*), Colima warbler (*Vermivora crissalis*), roadrunner (*Geococcyx californianus*), mule deer (*Odocoileus hemionus*) and mountain lion (*Felis concolor*).

Cascade Head Experimental Forest and Scenic Research Area

The Cascade Head Experimental Forest was established in 1934. A part of this experimental reserve was incorporated within the unique Cascade Head Scenic Research Area established by Congress in 1974. The two areas together provide a 7 050-ha Biosphere Reserve on the Oregon coast (lat. 45° 02'N, long. 123° 59' W). The site is administered by the U.S. Forest Service. The Experimental Forest occupies the crest and slopes of a prominent basaltic headland which juts into the Pacific Ocean. Topography is generally rugged with elevations ranging from sea level to 525 m. The area has a maritime climate with cool summers and wet, mild winters (annual precipitation 248 cm); an important climatic feature is the fog which covers the headland many summer afternoons.

Dense forests of *Picea sitchensis* and *Tsuga heterophylla* are dominant biological features. Most of these forests reproduced following wildfires in the 1840's. These are extremely productive with standing crops (live biomass) in excess of 900 tons per ha in some mature forests and annual rates of production in excess of 30 tons per ha in some young stands. Some areas disturbed more recently are occupied by stands in which *Alnus rubra* is a major or sole dominant. Natural meadows occur on some exposed portions of the headland. Sea cliffs and rocky beaches are common providing habitat for numerous sea birds and haul-out areas for marine mammals such as northern sea lions.

The Experimental Forest has been a primary area for studies of the ecology and silviculture of coastal *Picea-Tsuga* and *Alnus rubra* forests. Growth and yield of natural stands, harvest methods, and regeneration of trees, and nutrient cycling, including the effects of *Alnus* on the nitrogen regime, have been major research subjects.

The Scenic Research Area adds the entire estuary of a small river although much of the estuary and adjacent slopes have been modified and are occupied by humans. Major objectives in this part of the Biosphere Reserve are restoration of the estuary and provision for human occupancy of adjacent slopes in manners consistent with maintenance of natural and scenic properties. The research program is focused largely on solution of management problems such as development of techniques for restoration of salt marsh areas which have been diked pasturelands.

Channel Islands National Monument

Channel Islands National Monument consists of two small islands (7 440-ha) off the southern California coast (lat. 34° 01'N, long. 119° 23'W) and has been administered by the National Park Service since it was established in 1938. Selection as a Biosphere Reserve was based on the recognition of a California Islands Biogeographic Province in the earlier International Union for the Conservation of Nature (IUCN 1974) classification. Anacapa Island is 15 km from the mainland and is a rugged rocky area about 8 km long and less than 1 km wide. Santa Barbara Island is over 60 km at sea and is also rugged; rocky bays and sandy beaches are present as well as vertical cliffs and gentler uplands. Most of the 35 cm of rainfall occurs in the winter; summers are warm and dry.

The area has an outstanding diversity of biota including many endemic species, which is the major reason it was established. Sea birds, many of which nest on the islands, and marine mammals, such as California sea lions (*Zalophus californianus*) and sea elephants (*Mirounga angustirostris*), are important elements. Floristic elements are also distinctive, one of the most conspicuous elements being the giant coreopsis (*Coreopsis gigantea*) which occasionally attains a height of 2-1/2 m. Research is focused largely on population and ecological studies of several faunistic groups including marine mammals and sea birds.

Central Plains Experimental Range

This 6 285-ha reserve is located in northeastern Colorado and is administered by the Agricultural Research Service (U.S. Department of Agriculture). The site is located on the Colorado Piedmont, (lat. 40° 49'N, and long. 104° 46'W), which is a large erosional depression carved from a high plains surface. Topography is gentle and rolling. The site is located immediately in the lee of the Rocky Mountains and, therefore, has a semi-arid continental climate which could be classed as a cool-steppe climate. Annual precipitation is 31 cm with about 50 percent occurring from May through August from thunderstorm activity. Winter climate is dominated by continental polar air masses. The lowest maximum monthly mean temperature is 7°C in both January and December.

Vegetation is generally described as native short grass prairie, and it is dominated by *Bouteloua gracilis* and *Buchloë dactyloides* supplemented by *Carex eleocharis* and *C. filifolia*. Several mid-grasses such as *Agropyron smithii*, *Stipa comata*, and *S. viridula* grow in association with the short grasses but seldom obtain sufficient densities to dominate. Leading browse species are *Artemisia frigida*, *Atriplex canescens*, and *Eurotia lanata*. Other common shrubs are *Chrysothamnus nauseosus*, *Gutierrezia sarothrae*, and *Artemisia tridentata*. *Opuntia polyacantha* is widely distributed. Common vertebrates include pronghorn antelope (*Antilocapra americana*), jackrabbit (*Lepus* spp.), thirteen-lined ground squirrel, (*Spermophilus tridecemlineatus*), northern grasshopper mouse (*Onychomys leucogaster*), and Ord kangaroo rat (*Dipodomys ordii*). The most common birds are

lark buntings (*Calamopsiza melanocorys*) and horned larks (*Ermophila alpestris*).

Since it was established in 1939, the Central Plains Experimental Range has been extensively used for research on range management and structure and function of short grass prairie ecosystems. Much of the early work had to do with range management such as studies of stocking rates, grazing intensities, plant phenology, plant ecology, timing of summer grazing, fertilization, and range improvement. In more recent years, the scope of studies has increased, particularly since it was selected as the intensive site for the Grasslands Biome Project (U.S.–IBP) in 1967. A large team from this project has analyzed the fundamental structural and functional characteristics including structural features of trophic compartments, and their variation in time and space and under stress. There has been a broad array of studies relating to ecosystem processes such as primary and secondary production, energy flow, nutrient cycling, and abiotic and biotic controls on material and energy cycles. This information is being synthesized using mathematical models as well as classical techniques. It would be fair to describe the Pawnee Site, a small section of the Central Plains Experimental Range, as probably the best understood and described segment of North American grassland.

Coram Experimental Forest

This 2 984-ha area is located in the northern Rocky Mountain region of western Montana (lat. 48° 25'N, long. 114° 0'W) and is administered by the U.S. Forest Service. The mountainous tract consists generally of steep topography with some glacier till plains and terraces; it was heavily glaciated in the past. Bedrock consists of argillites, quartzites, and impure limestone.

The area is considered to be highly representative of vast acreages of northern Rocky Mountain mixed conifer forests. The primary type consists of *Pseudotsuga menziesii-Larix occidentalis*. With an elevational range of 1 022 to 1 952 m, there is a considerable range in environments and communities, however, from climax *Pseudotsuga* forests at lowest elevations (25 percent of the area) through mesic midslope forests (64 percent) to subalpine forest ecosystems dominated by *Abies lasiocarpa* and *Picea engelmanii* (11 percent). In addition to the *Larix* and *Pseudotsuga*, the midslope forests also contain substantial numbers of *Pinus monticola*, *Thuja plicata*, *Pinus contorta*, and *Tsuga heterophylla*. Most of the virgin forest is approximately 300 years old. The Coram Research Natural Area (338 ha) has been established as a major control area.

This Experimental Forest was established in 1933 and has been a site for intensive study of ecology and silviculture of forest ecosystems since 1946. Primary subjects which are currently being studied include entomology, pathology, phenology, hydrology, silviculture, and wildlife habitat.

Coweeta Experimental Forest and Hydrologic Laboratory

This 2 300-ha reserve is located in the southern Appalachian Mountains of southwestern North Carolina (lat. 35° 03'N, long. 83° 27'W) and is administered by the U.S. Forest Service. Topography is steep and rugged with elevations ranging from 675 to 1 575 m. Underlying rock is granite gneiss, mica gneiss, and mica-schist of pre-Cambrian origin. The soil mantle is relatively deep (averaging 90 to 150 cm) and porous. The climate is characterized by abundant precipitation (about 200 cm) and moderate temperatures (175 to 185 frost-free days).

Deciduous hardwood trees (there are nearly 60 species) are the dominant biologic feature. Generalized forest cover types are (1) northern hardwoods, (2) pine-hardwoods, (3) cove hardwoods, and (4) oak-hickory. The oak-hickory (*Quercus-Carya*) type is most extensive. In the coves (small moist basins) *Liriodendron tulipifera* and *Tsuga canadensis* are added to *Quercus* and *Carya* spp. Northern hardwood types occur at higher elevations and include *Acer saccharum*, *Betula alleghaniensis*, *Tsuga*, and *Tilia* with *Rhododendron* and *Kalmia* forming evergreen shrub understories. The *Pinus rigida-Quercus* forests are on dry ridges. The most significant disturbance to the natural condition has probably been the essential elimination of a forest dominant, *Castanea dentata*, by an introduced blight.

This reserve has a long and distinguished research history beginning with its establishment in 1934 as the major site for studies of the effects of forests and forestry practices on water yield and quality (Dils 1957). A major research technique has been the use of over 40 small (10- to 80-ha) unit watersheds as the basic units for experimental treatment and study. Major studies have included hydrologic consequences of mountain farming, woodland grazing, exploitive logging, forest cutting (with and without regrowth), removal of streamside vegetation, conversion from forest to grassland and from deciduous forest to *Pinus strobus* plantations, and normal forest practices. Movement of soil water has been studied using large size soil models. In recent years (partially in conjunction with its use as an intensive site in the Deciduous Forest Biome Project, U.S.-IBP), research on carbon and nutrient cycling has been intensified and is now a major element of the research program. Stream biology and forest succession are other important research areas. Coweeta has excellent on-site laboratory and data processing facilities.

Desert Experimental Range

This 22 513-ha tract is located in the Great Basin region of Utah (lat. 38° 40'N, long. 113° 45'W) and is administered by the U.S. Forest Service. Approximately 75 percent of the area is on alluvial slopes and valley bottoms with the remainder on mountainous rockland. The elevations range is from 1 547 in the playa to 2 565 m in the rocky hill lands.

The Experimental Range is representative of salt desert shrub (*Atriplex-Sarcobatus*) and pinyon-juniper (*Pinus-Juniperus*) woodland ecosystems. Salt desert shrub and associated types cover 20 391 ha with *Atriplex confertifolia*, *Eurotia lanata*, *Chrysothamnus stenophyllus*, *Artemisia spinescens*, *Artemisia nova*, *Ephedra* spp., *Oryzopsis hymenoides*, and *Bouteloua gracilis* as dominant species. Charactersitic vertebrates are great basin kangaroo rat (*Dipodomys microps*), jackrabbits, whitetail antelope squirrel (*Ammospermophilus leucurus*), and deer mouse (*Peromyscus maniculatus*).

Research on grazing management and wildlife habitat has been underway since 1934. The entire property is fenced along with a 740-ha control area, twenty 50-ha experimental pastures, and 43 enclosures of which the majority are located within the pastures. Basic ecosystem-oriented research is being accelerated to match current levels in applied programs.

Everglades National Park

This subtropical reserve of 566 800 ha was established in 1947 on the southwestern tip of Florida and is administered by the U.S. National Park Service. It is an extremely rich biotic region dominated by wetland ecosystems of various types (George 1972). Porous limestone underlies this low, flat region. The complex ecosystems result from mixtures of tropical and temperate organisms, the effects of cycles of flood, drought and fire, and subtle variations in temperature and substrate conditions which represent the basic environmental mosaic.

Major ecosystem complexes include: Florida Bay and its associated sea grass beds, keys, mud banks, and coastal prairies; mangrove swamps in brackish water regions; tree-island glades, the fresh-water region famous for the "river of grass," including bay head, cypress head, willow head, hardwood hammock, sawgrass, and dwarf cypress communities; and the pine and hammock ridge ecosystems found on elevated "ridges" (perhaps 2 m above sea level). Fire is very important in the pine (*Pinus elliottii* var. *densa*) and hammock ridge ecosystems. Tree-island glade ecosystems are naturally dependent upon periodic floods and occasional fires (during drought years) to maintain their natural balance. Mangrove swamps can be differentiated into 3 main types: *Rhizophora mangle* (red mangrove), which is very water tolerant and grows well out into mud flats; *Avicennia nitida* (black-mangrove) which grows on areas exposed at low tides and has pneumatophores; and *Laguncularia racemosa* (white-mangrove) that grows farther back from the water. The mangrove-estuary complexes are extremely important and productive biological areas.

The biota is very rich with over 24 rare and endangered vertebrates including several wading birds, American crocodile (*Crocodylus acutus*), and green turtle (*Chelonia mydas*).

Research is usually linked with management programs and directed to: the role and use of fire; the control of exotic plants (*Casuarina*, *Melaleuca*, *Schinus*, and *Colubrina anaticus*); the rehabilitation of

abandoned farmlands; the effects of runoff levels on ecosystems; the fish populations and their distribution including fisheries in benethic habitats of Florida Bay (monitoring of water quality--salinity, temperature, dissolved O_2, pH, and turbidity)--is an integral part of these studies; and the ecology of several unique species including white ibis (*Eudocimus albus*), loggerhead turtle (*Caretta caretta*), bald eagle, American crocodile, wood stork (*Mycteria americana*), osprey (*Pandion haliaetus*) and roundtailed muskrat (*Ondatra zibethica*).

Fraser Experimental Forest

This 9 320-ha reserve is located in the central Rocky Mountain region in Colorado (lat. 39° 54'N, long. 105° 53'W) and is administered by the U.S. Forest Service. Steep, high mountain slopes with evidence of extensive glaciation are the most prominent topographic features; only about 10 percent of the area has slopes of 15 percent or less. Most of the soils are derived from gneisses and schists. Elevations range from 2 260 to 3 104 m.

The primary ecosystems present on this reserve are subalpine forests, alpine meadows, and some wet montane meadows. Virgin *Picea engelmannii-Abies lasiocarpa* forests cover 2 195 ha; *Pinus contorta* forests, 3 450 ha; *Populus tremuloides* stands, 125 ha; alpine tundra, 2 240 ha; and wet meadows and *Salix* communities 388 ha. There are also two small alpine lakes and 73.5 km of perennial streams. Typical fauna include elk, mule deer, white-tailed ptarmigan (*Lagopus leucurus*), and blue grouse (*Dendragapus obscurus*). This Experimental Forest was established in 1937. In addition to being highly representative of the forest and alpine ecosystems found in the central Rocky Mountains and the site of intensive research on watershed and timber management, this has been a primary area for the study of hydrological cycles in the Rocky Mountains.

Glacier National Park

This 410 000-ha tract was established in 1910 and is administered by the National Park Service. It is located in northwestern Montana (lat. 51° 45'N, long 117° 35'W) and was selected as being highly representative of the Rocky Mountain (northern subdivision) Biotic Province. Bedrock geology is dominated by metamorphic and igneous (extrusive and intrusive) materials in this uplifted mountain region. The area was heavily glaciated--molding most of the present landforms. Climate varies substantially over this rugged mountain reserve but it is wetter on the western than on the eastern slopes and there are substantial winter snowpacks.

A diverse array of ecosystems and biota are present: savanna-type *Pinus ponderosa* stands at the low elevation steppe-forest ecotone; luxuriant montane forests (including *Tsuga heterophylla* and *Thuja plicata* along with more widespread species such as *Pseudotsuga mensiesii* and *Pinus contorta*); subalpine forests and meadows; and

finally alpine landscapes. Notable faunistic elements include the mountain goat (*Oreamnos americanus*), elk, bighorn sheep (*Ovis canadensis*), moose (*Alces alces*) and grizzly bear (*Ursus horribilis*).

Current research includes: ecological studies of the grizzly bear and large ungulates; invertebrate surveys with one ecological study of stoneflies (Plecoptera); visitor impacts in subalpine and alpine areas and their reduction; geology; systematics of some of the floristic components; and impact of aluminum plant emissions on forest insect infestations. A particularly interesting research project involves an inventory of the forest ecosystems using gradient models and a sophisticated information storage and retrieval system; an immediate application of the work is provision for a real-time fire simulation model on which to base fire control decisions.

Great Smoky Mountains National Park

This 207 500-ha Park was established in 1934 and is located in the southern Appalachian Mountains in North Carolina and Tennessee (lat. 35° 43'N, long. 83° 20'W). It is administered by the National Park Service. Topography in this mature mountain region is rugged with elevations ranging from less than 500 m to 1 992 m atop Clingman's Dome. Sedimentary and metamorphic materials predominate--shale, siltstone, slate, limestone, and sandstone. Precipitation and temperatures show marked elevational gradients but average 56.5° F and about 150 cm annually at low elevation stations with much of the rain occurring during the summer growing season.

The outstanding biological feature of the reserve is the dense mantle of vegetation. Richly diverse hardwood forests dominate--*Liriodendron tulipifera*, *Quercus* spp., *Fagus grandifolia*, *Carya* spp., and *Pinus* spp. are characteristic. Subalpine *Picea rubens-Abies fraseri* forests dominate above 1 500 m. Grass and heath balds are conspicuous nonforested areas on some mountain summits and ridges. Biologically the region is the richest in the Eastern Forest Biotic Province.

Much of the current research focuses on systematic, population, and interspecific competition studies of organisms including some groups of vascular plants, fungi, land snails, and especially salamanders. Management-oriented research includes studies of the ecology and impact of the introduced European boar (*Sus scrofa*) and ecology of the black bear (*Ursus americanus*) using radioisotopes to trace movements.

H. J. Andrews Experimental Forest

This 6 100-ha tract was established in 1948 and is located on the western slopes of the Cascade Range in Oregon (lat. 44° 15'N, long. 122° 10'W) and is administered by the U.S. Forest Service. Mature mountainous topography (elevational range 435 to 1 631 m) with moderate to steep slopes is characteristic of this region of Miocene-Pliocene extrusives (andesite, basalt, and other pyroclastics).

The climate is winter-wet, and summer-dry with an annual precipitation of 239 cm and substantial winter snowpack (up to 3 m or more) at higher elevations.

The outstanding ecosystems are dense, virgin forests of *Pseudotsuga menziesii*, *Tsuga heterophylla*, *Thuja plicata*, and *Abies* spp. which are predominantly old growth (>400 years old) and associated streams. Vegetation is zoned with *Pseudotsuga* dominating up to 1 200 m and *Abies* spp. above this elevation. Younger (130-year-old) stands of *Pseudotsuga* and *Abies procera* are also common. Standing crops are often large (1 000 metric tons per ha or more).

Past and current research programs are extensive including long-term Forest Service studies of effects of management practices on water yield and quality and ecosystem analyses (carbon, water, and nutrient cycles) by the Coniferous Forest Biome Project, (U.S.-IBP), which selected the H. J. Andrews as an intensive study site. Current emphases include: structure and function of stream ecosystems along a size gradient (from the allochthonous-dominated first order streams which lack fish to fifth order and larger); energy, nitrogen, and water budgets of old-growth tree canopies; geomorphic processes and erosion (especially mass movements) under natural and managed conditions; ecosystem processes (productivity, decomposition, etc.) along environmental gradients; and nutrient, water, and carbon budgets for natural and treated watersheds.

Hubbard Brook Experimental Forest

The 3 075-ha Hubbard Brook Experimental Forest is located in the White Mountains of New Hampshire (lat. 43° 57'N, long. 71° 42'W) and is administered by the U.S. Forest Service. It was established in 1955 to serve as the intensive site for watershed research in the northern Appalachian Mountains. Terrain is typically steep and rugged with elevations from 230 to 1 010 m. The area was heavily glaciated, and soils are predominantly well-drained podzols on till. Average precipitation in this continental climate is 1 240 cm, well distributed throughout the year; 1/3 to 1/4 of the precipitation occurs as snow which persists from mid-December until mid-April.

The Hubbard Brook drainage was logged over 50 years ago, but the forests today are dominated by representative northern hardwoods. *Fagus grandifolia*, *Betula alleghaniensis*, *Betula papyrifera*, *Acer saccharum*, *Acer rubra*, and *Fraxinus americana* are most important. Ten percent of the trees are conifers--*Picea rubra*, *Abies balsamea*, and *Tsuga canadensis*.

The Experimental Forest is the location for intensive research on water, nutrient, and carbon cycles by scientists from the U.S. Forest Service and several U.S. universities, particularly Cornell and Yale. One major discovery has been that large losses of nutrients can occur when vegetative regrowth is prevented following forest cutting. Losses are less when regrowth is allowed. Effects of acid rain and of forest cutting on water yields and snowmelt floods are also under study along with numerous autecological studies of various plants

and animals and an ecosystem analysis of a small lake. Important forest succession and lake models have been developed using Hubbard Brook data.

Jornada Experimental Range

This 78 297-ha reserve is located in southern New Mexico (lat. 32° 37'N, long. 106° 45'W) and is administered by the Agricultural Research Service (U.S. Department of Agriculture). Annual rainfall in this arid region is about 23 cm of which half falls during July, August, and September. Approximately 79 percent of the reserve is located on the undulating or gentle slopes of the Jornada Plain which consists of unconsolidated pleistocene detritus. The remainder is located on the steep slopes of the St. Andres Mountains which consist of paleozoic marine sediments.

The biota generally segregate according to the major physiographic units. *Bouteloua-Hilaria* shrub steppe occupies 58 500 ha on the playas (800 ha), plains (42 000 ha), and bajadas (15 700 ha) of the Jornada Plain. Dominant grasses on the sandy soils are *Bouteloua eriopoda*, *Sporobolus* spp. and *Aristida longiseta*. Relatively recent brush invasion is common and includes *Prosopis glandulosa*, *Atriplex canescens*, *Gutierrezia sarothrae*, and *Yucca elata*. In lower lying areas with heavier soils, primary grasses are *Hilaria mutica* and *Scleropogon brevifolius* with *Flourensia cernua* as the principal invading shrub. The mountain vegetation types, which cover 16 600 ha, are primarily shrub communities (*Larrea divaricata*, *Prosopis*, *Cerocarpus*, *Acacia*, *Artemisia filifolia*, etc.) and woodlands of *Juniperus osteosperma* and *Pinus cembroides*. Major vertebrates include a large resident mule deer population and a small band of desert bighorn sheep.

Research has been underway at this site since it was established in 1912. In the early years, the focus was almost entirely upon range management problems. Current research efforts, in addition to range and wildlife habitat research, include studies of carbon, water, and nutrient cycles in desert grasslands. The Jornada Experimental Range was used as a major study site by both the Grassland and Desert Biome Projects of the U.S.–IBP.

Luquillo Experimental Forest

This 11 300-ha tract was established in eastern Puerto Rico (lat. 18° 21'N, long. 65° 45'W) in 1903 and is administered by the Institute of Tropical Forestry (U.S. Forest Service). Elevations range from 150 to 1 080 m. Four major ecosystems are recognized: (1) Subtropical Wet Forest on foothills and slopes below 600 m (7 900 ha). Annual precipitation is 175 to 250 cm. In well-developed forests, the average number of tree species is 33 per acre with *Dacryodes excelsa* characteristic; (2) Subtropical Rain Forest or Montane Thicket on valleys and gradual slopes above 600 m (2 000 ha). Annual precipitation is 250 to 450 cm. Two tree strata average 23 tree species per acre with *Cyrilla racemiflora* characteristic;

(3) Palm Brake on steep slopes and arroyos above 450 m (1 200 ha). Soils are usually shallow and unstable and precipitation high (225 cm or more). Sierra palm (*Euterpe globosa*) is characteristic; and (4) Dwarf Forest or Elfin Woodland on the most exposed peaks and ridges above 800 m (240 ha). High winds, precipitation 375 cm or more, and saturated soils are characteristic. The tree canopy is from <1 to >6 m in height with abundant mosses and epiphytes.

The Luquillo is a major site for research on the ecology and management of tropical forests. Management research includes studies of exotic plantations which cover 400 ha. Ecological research includes studies of the natural communities (e.g., Ewel and Whitmore 1973) and of the very rare Puerto Rican parrot (*Amazona vittata*) which is also the subject of an intensive management program. Ecosystem-level research has been carried out at an intensive site (Odum 1970).

Mount McKinley National Park

This 784 900-ha reserve is located in the Alaskan Range of central Alaska (lat. 63° 48'N, long. 153° 02'W) and is administered by the National Park Service. Topography is varied including extensive gently undulating or sloping lowlands and rugged, heavily glaciated mountains; the summit of Mount McKinley is, of course, the highest point at 6 194 m, 4 800 m above the surrounding foothills. The climate is severe with long cold snowy winters and short summers.

The major ecosystems within the reserve are tundra communities of various types with *Eriophorum*, *Carex*, *Salix*, and *Betula* species as characteristic components. *Taiga* is relatively limited because the upper timberline occurs at about 825 m. *Taiga* species (*Picea mariana*, *Picea glauca*, *Populus* spp., and *Betula papyrifera*) occur in relatively narrow strips along river valleys. The ungulates and large predators are a notable feature of the reserve and include caribou, Dall sheep (*Ovis dalli*), moose, wolves, and grizzly bear. Current research is focused most heavily on the faunistic components--their ecology and food habits and carrying capacity of the ecosystems for ungulates such as moose.

Noatack National Arctic Range

This 3 000 000-ha tract is representative of the Alaskan Tundra Biotic Province. It has been proposed for addition to the National Wildlife Refuge system and is currently administered jointly by the Bureau of Land Management and Fish and Wildlife Service with the advice of the National Park Service (all agencies in the U.S. Department of the Interior). It is located in northwestern Alaska just north of the Arctic Circle and consists of two major arctic river valleys--those of Noatack and Squirrel Rivers (lat. 67° 58'N, long. 162° 15'W). Elevations range from sea level to over 2 400 m. Topography is generally rolling except near the headwaters. Paleozoic sedimentary and metamorphic rocks dominate, and permafrost and periglacial phenomena occur throughout. Noatack has been described as similar to the Anadyr region of eastern Siberia.

Tundra dominates with tussock and shrub tussock communities the most common form. *Eriophorum vaginatum* is the major vascular plant. Fell fields and barrens with open discontinuous vegetation are second in importance to tussock communities. Tundra brush communities are also common and consist of *Betula nana*, *Salix pulshra*, or riparian willow (*Salix* spp. and *Alnus crispa*) types. *Taiga*, consisting of *Picea glauca* stands, occur as far north as the Noatack River. *Populus* groves occur in protected locations.

Wildlife is abundant including 200,000 migrants from the Arctic caribou herd, grizzly bear, Dall sheep, moose, wolverine, and wolf. The most northerly chum salmon run occurs in this Biosphere Reserve.

Scientific expenditions have been conducted to the area, but no permanent research programs or facilities are presently located there. In addition to unpublished reports of expeditions or survey teams, much relevant information has been published in connection with the Cape Thompson investigations (Wilimovsky and Wolfe 1966) and in individual scientific reports.

Olympic National Park

This 362 850-ha reserve is located on the Olympic Peninsula of northwestern Washington State (lat. 47° 54'N, long. 123° 00'W) and is administered by the National Park Service. The majority of the area is a rugged mountainous region of varied bedrock geology, steep slopes, and extensive evidences of glaciation. A part of the reserve is a narrow strip on the coastal plain along the Pacific Ocean; topography is moderate in this section. Elevations range from sea level to 2 428 m atop Mount Olympus. Despite the relatively low elevation of the mountains several peaks currently have significant alpine glaciers. This is a consequence of the very wet, cool climate of this coastal region. Precipitation reaches 500 cm on Mount Olympus and is nearly as heavy in the western valleys; it declines rapidly on the eastern (lee) slopes of the mountains.

The outstanding biological features of the reserve are the dense coniferous forests, which occupy all but the highest peaks and ridges, and the herds of Roosevelt elk (*Cervus canadensis roosevelti*). The forests of the western valleys are most distinctive--the so-called "Olympic Rain Forests" of *Picea sitchensis*, *Tsuga heterophylla*, and *Acer macrophyllum* (Franklin and Dyrness 1973). *Pseudotsuga menziesii* is a common associate on the western slopes as is *Thuja plicata* on the coastal plain. *Abies amabilis-Tsuga heterophylla* forests dominate the interior of the Olympic Mountains and *Pseudotsuga* and *Tsuga* the drier montane forests of the eastern slopes (Fonda and Bliss 1969). Subalpine forests and meadows are common above about 1 500 m.

Current research includes studies of: ecology of non-native mountain goat populations, human impact, particularly in subalpine and alpine regions, mass balance of Blue Glacier, ecology of several small mammals, and succession and environmental relations in forests and subalpine meadows and at timberline.

Organ Pipe Cactus National Monument

This 134 000-ha reserve is located in southern Arizona along the Mexican border (lat. 32° 14'N, long. 113° 05'W) and is administered by the National Park Service. Varied topographic conditions exist from gentle valleys and plains to jagged ridges and peaks with deep canyons. About half of the 24 cm of annual precipitation occurs from July through September. Temperatures of 35 to 40°C are common in the summer; subfreezing nighttime temperatures occur occasionally during the winter.

Several types of desert ecosystems are generally recognized. Upland Arizona succulent deserts in the eastern half of the monument are characterized by cacti including *Carnegiea gigantea* (saguaro), *Lemaireocereus thurberi* (organ pipe), *Opuntia* spp. (prickly pears and chollas), *Ferocactus* spp. (barrel), *Echinocereus* spp. (hedgehog), and *Mammillaria* (pincushion). *Agave* spp. are common along with several desert "trees" such as *Olneya tesota* (ironwood), *Cercidium* spp. (paloverde), and *Acacia* spp. The central Gulf Coast phase of the Sonoran Desert, which is also present, contains additional unusual plants such as *Bursera microphylla* (elephant tree) and *Lophocereus schotti* (senita cactus). California microphyll desert is characterized by *Larrea tridentata* and *Franseria* spp.; it is found on the western edge of the monument. A distinctive desert fauna is present including many reptiles (e.g., 27 snake taxa and the desert tortoise, (*Gopherus agassizi*).

Rocky Mountain National Park

This 106 160-ha reserve is located astride the crest of the Rocky Mountains in north central Colorado (lat. 40° 29'N, long. 106° 06'W). It is administered by the National Park Service. Steep mountain slopes with extensive evidence of glaciation are the most prominent biological features; elevation ranges from about 2 400 to over 4 000 m on some peaks along the crest of the Rocky Mountains.

The major ecosystems present are the montane and subalpine forests and extensive tracts of alpine tundra. Montane forests are typified by *Pinus ponderosa* and *Juniperus* at lowest elevations and by *Pseudotsuga menziesii* and *Pinus contorta* at middle elevations. Above 2 700 m, subalpine forests of *Picea engelmannii*, *Abies lasiocarpa*, and *Pinus flexilis* dominate. Alpine ecosystems are varied, but a tundra of *Koeleria cristata*, *Carex* spp. and other herbs is most characteristic. Among the distinctive ungulates are elk, mule deer, and bighorn sheep. Current research includes: a 15-year study of alpine tundra recovery following human trampling, several geologic studies, ecological studies of ungulates and several bird species, ungulate habitat condition and trends, ecology and epidemiology of vector-borne diseases, and an inventory of aquatic resources.

San Dimas Experimental Forest

San Dimas is a 6 947-ha tract located in the San Gabriel Mountains of southern California (lat. 34° 12'N, long. 117° 46'W) and administered

by the U.S. Forest Service. This area has a typical Mediterranean climate with mild, wet winters and hot, dry summers (mean annual precipitation 67 cm). Topography (elevational range 381 m to 1 615 m) is generally steep (average slope 68 percent) and extensively dissected by steep-walled canyons; metamorphic and granitic formations dominate.

Vegetation types are: 47-percent chamise chaparral (*Adenostoma fasciculatum*, *Ceanothus crassifolius*, and *Arctostaphylos glauca*); 24-percent scrub oak (*Quercus dumosa*, *Q. wislizenii*, *Ceanothus oligathus*, and *Cercocarpus betuloides*); 12-percent sage and barren areas (*Salvia apiana* and *Eriogonum fasciculatum*); 7-percent riparian woodland (*Alnus rhombifolia*, *Acer macrophyllum* and *Umbellularia californica*); and the remainder in woodland sage (*Quercus/Salvia*), mixed chaparral, and *Pseudotsuga macrocarpa*. A 554-ha control area (Fern Canyon Research Natural Area) incorporates examples of all of these types. Most of the Experimental Forest was burned by wildfire in 1960 (a natural phenomenon for the type) and successional development is well understood. Characteristic vertebrates are mule deer and dusky-footed woodrat (*Neotoma fuscipes*).

Mooney and Parsons (1973) in their overview of research programs at the site describe San Dimas as probably the best known Californian Mediterranean ecosystem; intensive research has been underway since 1934. The hydrologic cycle was and continues to be a major focus including rainfall patterns in mountainous terrain, water use by vegetation, recovery following wildfire, and erosional processes (rates under natural conditions can average as high as 8 500 kg/ha). In recent years, overall carbon and nutrient budgets and ecology of individual species have received increased attention.

San Joaquin Experimental Range

This 1 861-ha area is located in the Central Valley region of California (lat. 37° 05'N, long. 129° 43'W) and is administered by the U.S. Forest Service. It has a Mediterranean climate with an average annual precipitation of 45 cm (range 22 to 90 cm). The site occupies rough granitic foothills ranging from 213- to 518-m elevation along the western slopes of the Sierra Nevada Mountains. Primary vegetation types are annual grasslands (*Bromus* spp., *Festuca* spp., *Erodium* spp., and *Trifolium* spp.) at lower elevations and oak woodlands (*Quercus* spp. and *Pinus sabiniana*) at higher elevations.

This area was established in 1934 and has been extensively used for range management research. Current programs include: wildlife ecology in annual grasslands, above- and below-ground biomass production, invertebrate populations and consumption, decomposition; relationship between abiotic factors and ecosystem processes, vegetation and cattle responses to various management strategies, and development of improved plant varieties for rangeland seeding. Much of the current ecosystem work was developed and is being carried on as one of the coordinating sites in the Grassland Biome Project (U.S.–IBP).

Sequoia-Kings Canyon National Parks

This 342 754-ha reserve consists of two adjoining Parks which are administered by the National Park Service. They are located in the central Sierra Nevada mountains of California (lat. 36° 52'N, long. 118° 93'W), a rugged topographic region composed mainly of granitic rock. The general elevation is 1 300 to 4 000 m in Kings Canyon National Park and 500 to 4 200 m in Sequoia National Park. The climate is summer-dry and winter-wet with strong elevational effects on precipitation and temperature. Heavy winter snowpacks develop at higher elevations.

The dominant biological features of both Parks are the montane and subalpine forest ecosystems. The montane forests are mixtures of *Pinus lambertiana*, *P. ponderosa*, *Libocedrus decurrens*, and *Abies concolor*. In subalpine regions, forests of *Abies magnifica*, *A. concolor*, *P. contorta*, and *P. jeffreyi* are characteristic with *Tsuga mertensiana* and *P. albicaulis* near timberline. *Sequoiadendron giganteum* is a distinctive but scattered element of the montane mixed coniferous forests. Meadows and lakes are abundant at higher elevations. Research includes ecological studies of: *Sequoiadendron* (Hartesveldt et al. 1975), including some unusual studies of associated insects; *Quercus kelloggii*; mountain meadow origin and development; and several vertebrates such as black bear, bighorn sheep, and cougar (*Felis concolor*); and limnology of high lakes (including human impact). The role of wildfire in forest and chaparral ecosystems has received special emphasis, and there are pilot projects on use of controlled burns to restore natural conditions and to encourage *Sequoia* regeneration and on development of "let-burn" programs to limit wildfire control activities.

Stanislaus Experimental Forest

This is a relatively small (683-ha) reserve located on the western slopes of the Sierra Nevada mountains in California (lat. 38° 03'N, long. 19° 57'W). It is administered by the U.S. Forest Service. The site experiences cool, wet winters and dry, hot summers. Topography is rough with moderate to steep slopes, rounded ridges, saddles, and moderately deep canyons. The soils are derived from granite, and much of the area has been glaciated. Elevations range from 1 585 to 1 951 m.

Biologically, this area is considered to be representative of the Sierran mixed-conifer type which is dominated by *P. lambertiana*, *Abies concolor*, *P. ponderosa*, *P. jeffreyi*, and *Libocedrus decurrens*. At higher elevations, subalpine *A. magnifica* forests are encountered. Forest structures are quite complex. Associated species include *Alnus rhombifolia* along streams, *Cornus nuttallii* in the understory, and numerous brushy *Arctostaphylos* and *Ceanothus* species. Research was begun in this area in 1909, and this is probably the most intensively studied example of Sierran mixed-conifer forests. Most of the research was centered upon silvicultural problems such as regeneration of the important tree species and forest insect and diseases.

Three Sisters Wilderness

This 80 900-ha reserve was established as a Wilderness by Congress in 1964. It is located astride the crest of the Cascade Range in central Oregon (lat. 44°N, long. 121°W) and administered by the U.S. Forest Service. Topography in this region of Pliocene-Pleistocene volcanic rocks consists largely of a gently sloping plateau although steep, rugged slopes are encountered along major stream courses and on the slopes of glaciated valleys and individual volcanic cones and buttes. Elevations range from about 600 m on the west boundary to 3 000 m atop the Three Sisters (three large composite volcanoes) and around 1 600 m on the east boundary. Mild, wet winters and dry, cool summers are characteristic with snowpacks of 3 to 5 m or more developing in the subalpine and alpine regions (locations over 1 500 m in elevation); snowpacks may persist into August in these areas.

Several contrasting ecosystems are present. In the western third of the reserve, dense forests of *Pseudotsuga menziesii* and *Tsuga heterophylla* are characteristic and are broadly similar to stands found on the nearby H. J. Andrews Experimental Forest. At higher elevations are subalpine forests of *Tsuga mertensiana* and *Abies* spp., subalpine meadows, alpine rockfields, permanent snowfields, and glaciers. Subalpine lakes are abundant. East of the summit, in the rain shadow of the Cascade Range, mixed conifer forests of *Pinus contorta*, *Pseudotsuga menziesii*, *Abies grandis*, and *Pinus ponderosa* are encountered. *Pinus albicaulis* is a major timberline associate of *Tsuga mertensiana* in this area.

Virgin Islands National Park

This 6 130-ha reserve provides for representation of the Lesser Antillean Biotic Province and has been administered by the National Park Service since designation as a National Park in 1956. It is located on St. John Island (lat. 18° 15'N, long. 64° 00'W) most of which has, unfortunately, been disturbed since first settlement in 1718. The Park includes a large area of lush, second-growth tropical forest (a mixture of native and introduced plants), coral reef gardens, and offshore rocks and caps. St. John is of sedimentary and volcanic origin with a maximum elevation of almost 400 m. Average rainfall is about 100 cm. The reserve has an extremely rich biota including a broad array of tropical trees and other plant life forms, over 100 bird species, and coral-dwelling marine organisms.

Yellowstone National Park

This 900 000-ha reserve needs little introduction. Established as the first National Park in 1872 it is administered by the National Park Service. Yellowstone is located at high elevations (1 620 to 3 408 m) along the crest of the Rocky Mountains (lat. 44° 45'N, long. 110° 35'W) primarily within northeastern Wyoming. Much of the Park is a series of high rolling plateaus with volcanic activity as the primary agent of landscape creation and erosional processes (including glaciation) as a secondary agent.

Geyser basins, hot springs, and other geothermal features are prominent; this is the only existing U.S. Biosphere Reserve which was selected for its unique (geothermal) features and not as a representative of a biogeographic province. There are, however, significant biological features within the reserve including extensive montane forests (especially of *Pinus contorta*), many birds, and populations of well-known ungulates and large predators such as bison (*Bison bison*), elk, moose, pronghorn antelope, bighorn sheep, mule deer, and black and grizzly bear.

Despite the large numbers of visitors, large segments of the Park remain in a virgin state and are rarely visited. Current research includes an array of geological studies (including thermal, volcanic, and seismic aspects), ecological studies of fauna (including trout, raptors, grizzly bear, and aquatic birds), climatology, several studies on the ecology of thermal environments such as hot springs, forest classification and succession, and heavy metal pollution.

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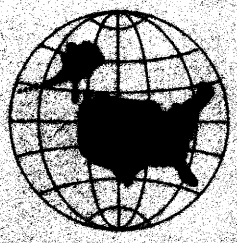

Biosphere Reserves in the United States and Their Relationship to the International Program, Man and the Biosphere

by

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INTRODUCTION

The focus of the Man and the Biosphere (MAB) Project No. 8--Conservation of Natural Areas and of the Genetic Material They Contain--is on the development of an international network of biosphere reserves representative of the biogeographic provinces of the world (UNESCO 1974). This project is based on the recognition that conservation of natural areas is of vital importance to the world for the role that these areas can play in scientific research, monitoring, education, and training, and in conservation of gene pools of plants and animals. It is also based on the view that, in the long term, ecosystem conservation can only succeed if we understand how these systems function with and without the presence of various human activities. Only long-term research and monitoring of man's actions can determine which of these actions are compatible with maintaining viable ecosystems and genetic diversity. The MAB Program is concerned with the impacts and ecological effects of human activities on different types of ecosystems or physiographic units, and countries are now developing cooperative interdisciplinary research programs (UNESCO 1975). Experts involved in the preparation of the MAB projects have emphasized the need for further studies of natural ecosystems and for comparison studies and experimental research on variously modified ecosystems. Biosphere Reserves, which can include both natural and modified ecosystems are basic logistic resources for much of the research to be undertaken in MAB.

PROGRESS IN THE INTERNATIONAL MAB PROJECT NO. 8

A great deal of progress has already been made toward developing this international network of biosphere reserves. As of December 1975, 38 countries have proposed to United Nations Educational, Scientific, and Cultural Organization (UNESCO) a total of approximately 155 areas to be designated as biosphere reserves. Also, work sponsored by UNESCO, the International Union for the Conservation of Nature and Natural Resources (IUCN) and the United Nations Environmental Program (UNEP) has progressed on the classification of natural regions, regional and country surveys, and identification of areas appropriate for establishment as biosphere reserves.

Surveys are underway, or have recently been completed in Southeast Asia, eastern Africa, western Africa, Central America, north and west Europe, and in coastal ecosystems of the Mediterranean and northern Indian Ocean.

Another noteworthy development is that during 1975 an "Ecosystem Conservation Group" was established with representation from UNEP, UNESCO, IUCN, and the Food and Agricultural Organization. This group will have regular meetings to facilitate closer cooperation between these organizations in their programs relating to ecosystem conservation. The Biosphere Reserve Project is considered to be a joint effort of these organizations.

The considerable progress in the international development of MAB Project 8 has been due, in part, to the stimulus of the July 1974 U.S.-U.S.S.R. agreement to contribute to the implementation of the MAB Program. This agreement implemented designation of certain natural areas as biosphere reserves in which research will be conducted in conformity with the goals of the UNESCO program.

BIOSPHERE RESERVES IN THE UNITED STATES

The approach to developing a network of biosphere reserves in the United States is outlined under the basic purposes of these reserves which are identified as follows (UNESCO 1974):

A. Conservation or preservation:

> "To conserve for present and future use the diversity and integrity of biotic communities of plants and animals within natural ecosystems, and to safeguard the genetic diversity of species on which their continuing evolution depends."

Plans for developing a realistic network of reserves representative of the many biotic regions found in the United States will be carried out by Federal, State, local and private authorities. The U.S. MAB Directorate will work closely with such groups as the Federal Committee on Ecological Reserves and The Nature Conservancy in determining the range of existing public and private efforts to protect our natural areas and will recommend actions for a coordinated national program. The U.S. Directorate has begun by designating some of the best and most representative areas in the U.S. as biosphere reserves. These areas either have, or can develop with a few years, the capability to participate effectively in cooperative national and international MAB activities. On this same basis, a few additional areas will be selected as biosphere reserves.

In September 1976, the U.S. MAB Project No. 8 will begin a series of regional meetings in which each biosphere reserve unit (experimental and baseline areas) will develop management and research plans as part of a national system. Plan development for units of the network must include recognition of the legislative

mandates and administrative policies characteristic of each managing agency or organization participating in the system. Plans will include special provisions to relate activities of the United States program to activities of other countries that are participating in MAB 8. Several fundamental provisions are essential for each unit, such as: (1) a biosphere reserve plan that identifies and defines appropriate land use conditions and that is based on professionally conducted programs of research, (2) the creation of public awareness of the nature, purposes, and management objectives of the unit, and (3) the establishment of appropriate types of uses of the unit for environmental education and cooperative research programs.

An example of one type of activity which U.S. MAB has already undertaken is in the development of guidelines for management and conservation of coastal ecosystems. The work is based on extensive research and management experience in the protection of coastal areas. U.S. MAB proposes to assist in a UNESCO/UNEP-MAB project to develop guidelines for the management of coastal zones, within biosphere reserves of other types of protected sites, which will be based on case examples of research and experience in a variety of coastal ecosystem types (Dolan, et al., 1975).

B. Research and monitoring:

> "To provide areas for ecological and environmental research including, particularly, baseline studies, both within and adjacent to such reserves, such research to be consistent with the conservation objective."

In addition to activities discussed in other papers presented at this Symposium, the U.S. MAB Project 8 activities this year will include an inventory of research and monitoring activities currently being conducted and the development of plans for additional studies. An important element of these activities will be cooperative work under Project V-4.1, Biosphere Reserves, of the U.S.-U.S.S.R. Bilateral Agreement on Environmental Protection.

Research projects that are suggested for MAB Project 8 include:

(1) Ecosystem inventory and analysis (structure, function, stability, diversity, mineral and energy flows, modeling, etc.);
(2) Development of a means to test the representativeness of proposed biosphere reserve units;
(3) Examination of factors that influence the probability that a given unit will succeed in preserving the genetic material it contains. One activity that is being considered has to do with applications of biogeographical theory to reserve design and management. Its objectives would be to:

a. Apply current predictive theory to park and preserve situations to test theory validity;
b. Predict community structural changes likely to occur in preserves; and
c. Formulate design guidelines and management schemes which will maintain a steady state and minimize extinctions within animal preserves.

(4) Refinement and application of modeling techniques to permit prediction of future needs for data that will be derived from monitoring activities to be initiated.

Research and monitoring plans for biosphere reserves will be developed to consider the reserve's potential role in long term synoptic monitoring of the international network of reserves. Recommendations will also be developed for use of biosphere reserves as baseline areas for monitoring of terrestrial ecosystems in the Global Environmental Monitoring System of UNEP.

The multi-agency, multi-year, multi-project nature of the biosphere reserve program requires use of modern, easily updated, comprehensible, and flexible data handling systems. A major task for the U.S. MAB Committee during the coming year will be to consider the feasibility of developing an information management system suitable for ensuring both short and long term storage, retrieval, and manipulation of information

C. Education and Training:

"To provide facilities for education and training."

OBJECTIVES

The International Coordinating Council of MAB has emphasized that all MAB research projects should include students and have a strong training component and that education and training courses should be organized to permit student exchange between countries. The Council also suggested that exchange of students, teachers, training specialists, and scientists between MAB projects should be encouraged. In support of these recommendations, the U.S. Directorate for MAB Project 8 will emphasize the following:

(1) On-site training and environmental education in Biosphere Reserves. Model programs have been developed in National Environmental Study Areas in some of the biosphere reserves, and student and teacher training materials are available for field projects (U.S. Department of the Interior, National Park Service, 1972);
(2) Further incorporation of MAB information and concepts into appropriate existing programs of government agencies and private institutions and strengthening of these programs to convey information about MAB nationally and internationally.

An example is the International Seminar on Administration of National Parks and Equivalent Reserves sponsored by the School of Natural Resources, University of Michigan with cooperation of National Park Service, United States Department of the Interior; Parks Canada, Department of Indian and Northern Affairs, Canada; and the National Commission of Public Works in Natural Parks, Secretary of Public Works, Republic of Mexico. The seminar, which is held each year in August, includes visits to parks and reserves in the United States, Canada, and Mexico.

The Seminar is designed for administrators, professional personnel, and conservation leaders responsible for the establishment and development of park and reserve systems and associated programs throughout the world. This program now includes MAB seminars and visits to biosphere reserves.

(3) Preparation of audiovisual and informational materials on MAB, especially on the national and international network of biosphere reserves.

It is suggested that the U.S. and the U.S.S.R. exchange such materials for purposes of developing information programs on Project V-4.1.

CONCLUSION

Biosphere reserves are a means to strengthen existing national and international research and conservation programs. The strength of the concept, unlike that of most nature conservation programs, lies in the integration and use of biosphere reserves as part of the national and international MAB program.

The United States will develop a number of areas to serve as bases for participation in a national and international program oriented to research, conservation, education, and training.

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APPENDIX

United States Man and Biosphere (MAB) Project Areas (Nov. 1977)

Following is a list of the 14 MAB project areas (Directorates) and a brief explanation of their emphasis in the United States. Also included with each project is the name of the U.S. Directorate Chairman.

1. *Tropical Forests:* Ecological effects of increasing human activities on tropical and subtropical forest ecosystems. A conceptual model for tropical forest management will be developed, using available information and defining specific inputs and outputs in ecological and economic terms.

Chairman: Frank B. Golley, Executive Director, Institute of Ecology, University of Georgia, Athens, Georgia 30601.

2. *Temperate Forests:* Ecological effects of different land uses and management practices on temperature and mediterranean forest landscapes. Baseline environmental monitoring programs and analyses of the effects of changing environmental conditions will be used to develop alternative management strategies for multiple use of temperate and mediterranean forest ecosystems.

Chairman: David Reichle, Associate Division Director, Environmental Sciences Division, Oak Ridge National Lab., P.O. Box X, Bldg. 2001, Oak Ridge, Tennessee 37830.

3. *Grazing Lands:* Impact of human activities and land use practices on grazing lands--savanna and grassland (from temperate to arid areas). The existing condition and potential of grazing lands will be determined, and physical, biological, environmental, and socio-economic effects of conflicting uses will be determined.

Chairman: David B. Thorud, Assistant Director, Southeastern Forest Experimental Station, P.O. Box 2570, Asheville, North Carolina 28802.

4. *Arid Zones:* Impact of human activities on the dynamics of arid and semi-arid ecosystems. Causal relationships in arid land degradation will be analyzed with the view toward development of long range strategies for arid land development consistent with carrying capacities, weather conditions, and research utilization.

Chairman: Jack Johnson, Director, Office of Arid Lands Studies, University of Arizona, 845 N. Park Avenue, Tucson, Arizona 85710.

5. *Fresh water:* Ecological effects of human activities on the value and resources of lakes, marshes, rivers, deltas, estuaries, and coastal zones. Research, education, and training activities will be used to develop management strategies that will provide a predictive capability for establishing the quality and quantity of water available, and identify conflicts that will arise because of limited local or regional supplies.

Chairman: (5A--Inland Resources) Edward Fernald, Florida Resources & Environmental Analysis Center, Florida State University, Tallahassee, Florida 32306.

Chairman: (5B--Coastal Resources) Jack R. Van Lopik, Dean, Center for Wetland Resources, Louisiana State University, Baton Rouge, Louisiana 70803.

6. *Mountains:* Impact of human activities on mountain and tundra ecosystems. Emphasis will be given to development of techniques for prediction of carrying capacity of mountain ecosystems for multiple use, including tourism. Analysis of the ecological and socio-economic impacts of tourism, industrial development, and resource exploitation will be examined in high latitude areas.

Chairman: (6A--Mountains and Tundra--Low Latitudes) Jack Ives, Director, Institute of Arctic & Alpine Research, University of Colorado, Boulder, Colorado 80309.

Chairman: (6B--Arctic) Robert B. Weeden, University of Alaska, Fairbanks, Alaska 99701.

7. *Islands:* Ecology and rational use of island ecosystems. Environmental and socio-economic changes associated with tourism and industrial development will be examined in order to develop improved strategies to preserve some of the features of these fragile ecosystems consistent with human needs.

Chairman: (7A--Pacific) Roland W. Force, 320 E. 65th Street, New York, New York 10021.

Chairman: (7B--Caribbean) William S. Beller (EPA), 2701 Largo Place, Bowie, Maryland 20715.

8. *Biosphere Reserves:* Conservation of natural areas and of the genetic material they contain. The 28 Biosphere Reserves established thus far in the United States are part of an international system of reserves with the primary objectives of conservation of genetic diversity, baseline environmental research and monitoring.

Cochairmen: (Conservation) Carl M. Berntsen, Director, Timber Management Research, U.S. Forest Service, Department of Agriculture, Washington, D.C. 20520; Vernon C. Gilbert, Associate Chief Scientist, National Park Service, Department of the Interior, Washington, D.C. 20240.

9. *Pesticides/Fertilizer:* Ecological assessment of pest management and fertilizer use on terrestrial and aquatic ecosystems. Included here are studies of methods of transport; behavior and reactions of specific compounds in water and terrestrial environments are related to their physical properties; protective clothing; specific formulation of pesticides to reduce environmental contamination; and disposal of contaminants.

Chairman: Virgil H. Freed, Director, Environmental Health Science Center, Oregon State University, Corvallis, Oregon 97331.

10. *Engineering Works:* Effects on Man and his environment of major engineering works. Attention will be given to concerns which arise in a wide variety of engineering applications including: siting for environmental protection; displacement and relocation of populations including the questions of equity; evaluation of effects; and improved predictive techniques to assist in decision strategies.

Chairman: C. P. Wolf, Environmental Psycology Program, CUNY Graduate Center, 33 W. 42nd Street, New York, New York 10036.

11. *Urban Ecosystems:* Ecological aspects of urban system with particular emphasis on energy utilization. The initial thrust will be concerned with water management in urban systems, emphasizing human well-being, land use, and energy considerations.

Chairman: Brian Mar, Associate Dean, College of Engineering, FX-10, University of Washington, Seattle, Washington 98105.

12. *Demographic Change:* Interactions between environmental transformations and the adaptive, demographic, and genetic structure of human populations. Two dimensions of human population change will be examined including: rural urban migration and changes in human populations in the new and old environments; changes in health and welfare of human population in existing communities impacted by environmental change (e.g., tourism and industrial development in Samoa).

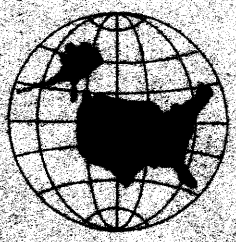
Chairman: Peter Kunstadter, East-West Center, 1777 East-West Road, Honolulu, Hawaii 96822.

13. *Perception of Environmental Quality:* Analysis of subjectively perceived environments is necessary to understand human well-being within any given environment. This project will be concerned with human perception of environmental hazards, environmental change, and environmental quality.

Chairman: Joachim F. Wohlwill, Division of Man-Environment Relations, S-126 Human Development Building, The Pennsylvania State University, University Park, Pennsylvania 16802.

14. *Pollution:* Develop a clearer understanding of the relation of pollution to the structure and functioning of terrestrial and associated aquatic ecosystems. Baseline information will be gathered through state-of-the-art measurements and observations and used to assess current environmental problems and predict future trends.

Chairman: Kenneth Hood, Office of Research and Development, EPA, 401 M Street, SW., Room 621, RD 683, Washington, D.C. 20460.



Characteristics of Research Programs at Established U.S. Biosphere Reserves

by

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INTRODUCTION

The ultimate objective of the Biosphere Reserve Project is to attain a coordinated network of Biosphere Reserves representative of the major ecosystem types, linked by exchange of information and of scientists. The specific objectives defined by the Man and the Biosphere (MAB) Task Force on Biosphere Reserves (UNESCO 1974) are:

1. "To conserve for present and future human use, the diversity and integrity of biotic communities of plants and animals within natural ecosystems, and to safeguard the genetic diversity of species on which their continuing evolution depends."

2. "To provide areas for ecological and environmental research including baseline studies, both within and adjacent to these reserves, such research to be consistent with the first objective."

3. "To provide facilities for education and training."

The component sites within the Biosphere Reserves should include representative and unique natural and man-modified areas of significant biomes.

The preservation of biotic diversity (Nature Conservancy 1975), provision for monitoring networks, and the maintenance of genetic diversity (Thompson 1975) are all important attributes of the Biosphere Reserves. This paper, however, will deal specifically with existing and potential ecological research programs at existing U.S. Biosphere Reserves. Before presenting a description of these studies, it is appropriate to characterize the unique potential contributions of a research site network.

Some research endeavors are most appropriately conducted under laboratory conditions, but most ecological theory arises from and is ultimately tested with studies from natural or modified ecosystems. The mandate for adequate field research opportunities

[1] At the time this work was accomplished the author was Program Director, Ecosystems Studies Program, National Science Foundation, Washington, D.C.

arises from the realization that man's long-term existence is predicated upon a comprehension of this ecological theory.

The establishment and maintenance of relatively large, diverse sites representative of each major biotic province confers a number of characteristics essential for future comprehensive ecological research endeavors:

1. At this point in time, it is impossible to anticipate and define the field situations and basic data necessary to answer future questions about the structure and function of ecosystems. So, carefully chosen sites, with accompanying information selected from past experience, will preserve our research options and provide an opportunity to test new hypotheses and management options.

2. Comparable information generated from a number of research areas will provide a data base from which to make ecological generalizations and propose rational research management strategies.

3. Continuous information from both biotic and abiotic parameters will permit the potential for detecting subtle degenerating environmental conditions before more overt and non-recoverable diminished environmental quality becomes evident.

4. Consistent long-term data on biotic and abiotic parameters will not only allow the separation of short-term fluctuations from long-term trends but will eventually show correlative relationships between and among chemical, physical, and biological factors.

5. As we now understand the behavior of ecological systems, there are certain basic driving variables which must be measured to permit the subsequent interpretation of research results. Biosphere Reserve sites, where these basic variables are routinely measured, will represent an economy in equipment and the opportunity to produce a uniform data base.

6. Restudy of a situation after a period of time may be extremely informative. This is especially true when the insults imposed on the system have changed or when the ecosystem itself is undergoing temporal or spatial changes. Established sites with driving variable data over the intervening years are essential for these studies.

7. Ecological research has now progressed in complexity so that many studies require expertise in a number of scientific disciplines, e.g. mathematical modeling, statistical methods, and analytical chemistry techniques. Established research sites function as research centers where expertise is shared with the greatest efficacy.

8. The convergence of scientists at one site enhances the resulting investigations in a number of ways. Since the site acts as a focal point, there is common ground for initial discussion and contemplation by scientists from different backgrounds. Many of our most fruitful research efforts are in the realms of interdisciplinary projects. At a site where all investigators are closely

associated, the communication channels are short-circuited so the ponderous procedures of scientific publications are obviated. Also, experiments utilizing a variety of interests and areas of expertise are conveniently organized and conducted. Finally, the probabilities for serendipitous discoveries from concurrent or spatially related studies are greatly enhanced.

The purpose of listing these eight points is to demonstrate that the Biosphere Reserve concept can augment international research potential from the standpoint of both the individual sites and from the collective array. The remainder of the paper will utilize some example studies to substantiate this contention. The chosen studies are primarily at the ecosystem level, since they most effectively depict the integrative possibilities at and between Biosphere Reserves.

EXAMPLES OF RESEARCH PROJECTS AT U.S. BIOSPHERE RESERVES

The following paragraphs will portray parts of the research programs from five U.S. Biosphere Reserves. The specific sites were selected as examples from different biotic provinces to demonstrate research at some of the more active sites.

Name	State	Location
Hubbard Brook Experimental Forest	New Hampshire	Northeast
H. J. Andrews Experimental Forest Willamette National Forest	Oregon	Northwest
Coweeta Hydrological Laboratory and Experimental Forest, Mantahala National Forest	North Carolina	Southeast
Central Plains Experimental Range	Colorado	Central Plains
Big Bend National Park	Texas	Southwest

Hubbard Brook Experimental Forest

One of the earliest site-oriented ecosystem studies is the Hubbard Brook Ecosystem Study which began about 1963 and has continued to the present. The Experimental Forest is in the White Mountains of north-central New Hampshire, ranging in altitude from 229 to 1 015 m and covering 3 076 ha of rugged terrain. The nearly mature forest is characterized by uneven-aged, well stocked, second-growth northern hardwoods maple (*Acer*) and beech (*Fagus*) with most coniferous species (*Tsuga, Picea, Abies*) at higher elevations and on north-facing slopes. The climate has short, cool summers and long, cold winters. Annual precipitation averaged about 123 cm, of which one-third to one-fourth is snow (Likens and Bormann 1975).

This site was ideally suited for the development of watershed input-output nutrient budgets because the watershed substrate is relatively impervious, the climate is moist, and biological communities are embedded in a much larger area of the same type of mature vegetation. As a result, by keeping records of meteorological inputs, geological outputs, and transfers within the system, it was possible to build nutrient budgets and calculate the geological inputs.

The biota and soils of the ecosystem were found to have developed a major, stabilizing influence on the output of nutrients measured as loss in the drainage waters. Even though the stream discharge ranged over four orders of magnitude during an annual cycle, the weekly chemical concentrations remained relatively constant for magnesium, sulfate, chloride, and calcium (Likens et al. 1967). Aluminum, nitrate, hydrogen ion, and potassium concentrations were slightly increased with increased discharge (Johnson et al. 1969). In the summer, biological activity appreciably reduced the concentration of nitrate and potassium in the stream water. Potassium was found to be the most sensitive index of annual biologic activity of the major alkalies and alkaline earths. Its concentration in stream water sharply decreased during periods of plant growth and increased with plant dormancy (Likens and Bormann 1975).

The deforestation study at Hubbard Brook is one of the best known ecosystem studies in the U.S. In 1965, all the vegetation on one of the experimental watersheds was cut; and the vegetation regrowth was inhibited for three summers by the periodic application of herbicides. This experimental manipulation was designed to determine the effects of (a) quantity and quality of stream water output from the watershed, and (b) fundamental biological and chemical relationships within the intrasystem cycle at the forest ecosystem. A number of ramifications were studied, but in summary, the flow of the discharge stream was increased 1.4 times, mostly in the summer, the output of particulate matter was up about 4 times, the net output of dissolved inorganic substances was up 14.6 times and the pH of the stream water was down from 5.1 to 4.3 (Likens et al. 1975). In addition to characterizing the basic responses to ecosystem manipulation, a whole host of interesting mechanistic questions have arisen from this study and a number of subsequent experiments are being conducted. These studies represent the type of ecological research which can and is being conducted on Biosphere Reserves. Not only is the resulting information of intrinsic ecological interest, but it is essential for rational planning of resource management.

H. J. Andrews Experimental Forest

The H. J. Experimental Forest occupies 6 500 ha and is broadly representative of the habitats along the northwestern coast of North America, the region known for its dense coniferous forests and rugged mountainous topography. The climate is maritime, wet with relatively mild winters and dry, cool summers. The vegetation is in two general zones with the lower one dominated by Douglas-fir (*Pseudotsuga menziesii*), western hemlock (*Tsuga heterophylla*), and

and western redcedar (*Thuja plicata*), and the upper one dominated by silver fir (*Abies amabilis*), noble fir (*Abies procera*), mountain hemlock (*Tsuga mertensiana*), and Douglas-fir.

The nitrogen budget of a small watershed dominated by old-growth Douglas-fir on the H. J. Andrews Experimental Forest was studied by a team of five investigators. The first step was to diagram the processes by which nitrogen moved through the system. Then the data from field studies were summarized as an annual budget, that is, the amount transferred along each pathway during 1 year along with the annual loss or increment in each storage compartment. In some cases data were not available from the field site, so literature values were employed under these circumstances (Sollins et al. 1976).

The estimated rate of nitrogen fixation was about eight times the measured nitrogen input by precipitation. Nitrogen losses were a small fraction of the total stand nitrogen dynamics and loss to groundwater amounted to only about 10 percent of the input or roughly the rate of accumulation. Hydrologic input accounted for only 11 percent of the total input; the remainder was due to nitrogen fixation. The only significant hydrologic transport of nitrogen was that from the litter layer to the soil, so the authors (Sollins et al. 1976) caution that conclusions regarding cycling of nitrogen based solely on hydrologic inputs and outputs can be misleading.

The nitrogen losses from this system were quite low, and only slightly greater than those reported for a 37-year-old Douglas-fir ecosystem (Cole et al. 1967). Although live biomass in the H. J. Andrews Experimental Forest watershed old-growth stand was decreasing, the detrital mass was accumulating. Therefore, both these studies supported the hypothesis of Vitousek and Reiners (1975) that losses of limiting elements remain small as long as biomass is accumulating (Sollins et al. 1976).

Coweeta Hydrological Laboratory and Experimental Forest

This 2 185-ha research installation in the Blue Ridge Province of the Appalachian Highlands represents the southeastern deciduous forest with 70 percent of the vegetation composed of oaks (*Quercus* species), hickories (*Carya* species), and red maple (*Acer rubrum*). Elevation in the study watershed ranges from 721 to 977 m with an average slope of 40 percent. Climate is classified as maritime with cool summers, mild winters, and adequate rainfall in all seasons.

The nutrient dynamics of the vegetation on this hardwood watershed can be summarized as below (Day 1974; Day and Monk 1975):

Transfers	Nutrients (kg ha^{-1}) K	Ca	Mg	Na
Input to woody parts	81.7	64.9	15.4	3.8
Output				
From woody parts				
Leaf-fall	.7	6.5	.1	.000 1
From reproductive parts				
Leaf-fall	3.6	1.1	.1	.000 1
From leaves				
Leaf-fall	43.3	35.5	10.7	.3
Leaching	25.8	3.9	2.3	2.3
Herbivores	4.0	4.1	1.1	.03

Leaf-fall represented the greatest nutrient output from the vegetation compartment (56 percent of the K, 69 percent of the Ca, 75 percent of the Mg, and 11 percent of the Na). Leaching was the second largest nutrient output flux from the vegetation and accounted for the largest loss of Na (Best 1971).

Individual species appeared to have different nutrient cycling strategies, such that canopy-sized trees were more important in the long-term nutrient cycle, nutrient rich understory species were more important in the annual cycle, and evergreen species were important in cycles of intermediate lengths because of short-term storage in their perennial leaves. Even though most of the annual nutrient uptake was recycled during the same season (92 percent of the K, 74 percent of the Ca, 93 percent of the Mg, and 68 percent of the Na), the accumulation of nutrients was considerable in this uneven-aged mature hardwood forest. Day (1974) found the nutrient amounts in the above ground parts to be 237.3, 555.4, 49.1, and 47.9 kg ha^{-1} for K, Ca, Mg, and Na, respectively.

Turnover of the nutrient pool in early old field successional stages is rapid and takes from 1 to 3 years since most of the plants are annuals or short-lived perennials. In mature forests, turnover of the vegetation nutrient pool takes much longer because a diversity of cycling strategies exist. Nutrients are stored in the different vegetation components and recycled at time intervals ranging from 1 to several hundred years, depending on the plant component and the species growth habit (Day 1974; Day and Monk 1975).

Central Plains Experimental Range

The site is located on the western edge of the Central Plains and is dominated by short grasses such as blue grama (*Bouteloua gracilis*). The topography is flat to gently rolling, and rainfall is only about 30 cm. The winters are moderately cold, and the summers hot and dry.

This was the field site for the International Biological Program Grassland Biome Pawnee site, and about 80 senior scientists worked here during the period of 1968 through 1974. Elaborate studies measured the response of this grassland ecosystem to various cattle grazing intensities. Four small watershed were enclosed to measure inputs and outputs of nutrients and water. In addition to studies of biomass and species population variables, there were a number of investigations which dealt with specific ecosystem and physiological processes.

The scientist at this site constructed a large, highly linked computer simulation model of this grassland. The model utilized mostly first order differential equations to describe the mechanisms of the ecosystem processes in such a way that predictions could be made about the flow and accumulation of carbon, water, and nutrients. The model, called "ELM" (Ecosystem Level Model), was developed primarily for this site though it has subsequently been adapted for other grassland types. It is capable of predicting the behavior of grasslands under various conditions, such as grazing intensities, additions of nutrients and water, and the occurrence of fire. In addition to the ecosystem level predictions, the model has been particularly useful for generating hypotheses about how the ecosystem works and for asking questions which lead to further experimental studies.

Big Bend National Park

This large National Park is situated on the Rio Grande River in the southwestern United States and includes the entire Chisos Mountain Range. Elevations range from about 500 m to over 2 300 m. The low elevation plains are dominated by the hot desert shrub, creosotebush (*Larrea tridentata*). The high mountain canyons support Arizona cypress (*Cupressus arizonica*), Ponderosa pine (*Pinus ponderosa*), and Douglas-fir (*Pseudotsuga menziesii*). Rainfall ranges from about 15 cm on the desert lowlands to above 50 cm in the highest mesic canyons.

A study which clearly shows the advantage of a long-term research site is being conducted in a high mountain canyon in the Chisos Mountains. Here the Mexican pinyon pine (*Pinus cembroides*) and the evergreen gray oak (*Quercus grisea*) dominate the upper canyon slopes, whereas the deciduous Graves oak (*Quercus gravesii*) is dominant on the mesic lower slopes and canyon floor between the ephemeral streams. By establishing permanent plots in 1964 and then following the seedling population dynamics for the following 9 years, Whitson[2/] has been able to draw several conclusions regarding vegetation population dynamics of these species: (a) younger seedling classes of these tree species experience greater mortality than older classes, (b) Mexican pinyon pine seedlings are apparently more drought tolerant than those of Graves oak, (c) environmental factors following 1964 are favoring Graves oak germination and establishment, suggesting

[2] Personal communication, Paul D. Whitson, Department of Biology, University of Northern Iowa, Cedar Falls.

that either significantly high germination periods or droughts may cause gaps or spikes in Graves oak age distribution profiles, and (d) the influence of a single drought in the southwestern United States may influence vegetation and species population structure for many decades thereafter.

Comparisons Across Biosphere Reserves

The previously described studies have dealt primarily with one community type in each of five U.S. Biosphere Reserves. It is possible, however, to compare ecosystem properties between community types in these large sites or between the sites themselves. Reichle (1975) compared the energy flow through successive trophic levels (green plant production, animal consumers, and microbial and invertebrate decomposers) in the prairie ecosystem at the Pawnee site on the Central Plains Experimental Range with an eastern deciduous forest at Coweeta Experimental Forest. Using calories per square meter per year scaled to the nearest power of 10, he showed that the forest had a larger standing crop of 10^8 as compared to 10^6 for the grassland. Most of the excess biomass in the forest was of woody supportive structures. The forest had a slightly higher annual net primary production, but the energy flow through the various trophic levels was similar in both systems. Both plant respiration and animal consumption values were remarkably close, even though large herbivores are more characteristic of the grassland. A large amount of energy (10^7 in the forest, 10^6 in the grassland) flowed through the decomposer organisms. This energy flux through the decomposers represented a relatively new appreciation of ecosystem dynamics, and its generality can only be tested by examining a number of different types of sites.

As noted previously in conditions where runoff is appreciable, considerable information about watershed mineral cycles is provided by observing element concentrations in stream flow (Reichle, 1975). The contrast of stream discharge values from different ecosystems in the same general geographic area may reflect how efficiently each type of ecosystem recycles nutrients. In comparing four vegetation types on the Coweeta site, Johnson and Swank (1973) showed that the grass-herbaceous ecosystem, which does not have the temporary storage capacity in woody structural material, was the least frugal in its utilization of nutrients. The coppice ecosystem, characterized by a dense stump-sprout regrowth of a clearcut forest, has a well developed root network and rapid growth rate and was very efficient in its uptake and recycling of nutrients. The White pine (*Pinus strobus*) ecosystem lost somewhat lesser amounts of nutrients than the mature hardwoods (Reichle 1975).

The nutrient budgets of the three forest Biosphere Reserves can be compared by using data summarized by Reichle (1975). The net loss of calcium, magnesium, and potassium from undisturbed watersheds at Coweeta, Hubbard Brook, and H. J. Andrews is given on the following page:

Watershed	Nutrient (net loss, kg ha^{-1}) Ca^{++}	Mg^{++}	K^{+}
Coweeta	0.7	1.9	2.0
Hubbard Brook	8.0	1.8	.1
H. J. Andrews	47.0	12.0	1.5

The Coweeta Watershed is on Precambrian amorphous geological materials, the Hubbard Brook has a granitic substratum, and the H. J. Andrews is underlain entirely by rocks of volcanic origin. Therefore, geology, soils, topography, climate, and vegetation are all involved with the interpretation of these nutrient budgets and, more generally, in the control of the structure and function of ecosystems. Ultimately, the behavior of these ecological systems can only be evaluated in the context of an array of sites like those represented in the Biosphere Reserves.

CONCLUSIONS

In the beginning of this paper, eight characteristics of a comprehensive network of ecological research sites were presented. Then, selected studies from five Biosphere Reserves illustrated these characteristics. Although there are some gaps in the present U.S. Biosphere Reserve coverage, it is clear that widely divergent systems like the moist coniferous forests of the H. J. Andrews Experimental Forest and the dry shrub deserts of Big Bend National Park will help insure that adequate systems will be available for future research. The comparison of nutrient budgets from the three forest Reserves showed the potentiality for testing generalities. Both the nutrient studies of Hubbard Brook Experimental Forest and the vegetation study at Big Bend National Park indicated the necessity of long-term records. The construction of a large ecosystem level simulation model, with the Central Plains Experimental Range as the focal point, demonstrated the role of a common site as aiding the communication between scientists of different disciplines. Finally, each site, with the associated research teams, has generated intellectual conditions which enhance the ecological research of the scientists, both individually and collectively.

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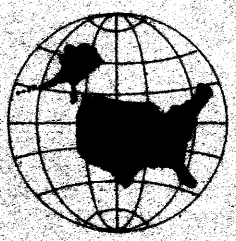

Exploration of the Concept of Marine Biosphere Reserves: What Could be Done and How

by

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INTRODUCTION

The Biosphere Reserve concept has been evolved largely for terrestrial areas, with some attention being given to the coastal zone, and almost none to the sea itself. The concept calls for core areas for baseline research and monitoring and buffer zones to protect the core and for use in studying the effects of human activities. Matched experimental areas can also serve the latter purpose. Thus, the Biosphere Reserve concept is an enlargement of traditional conservation objectives; it highlights research and monitoring, fosters preservation of habitats and ecosystems and the genetic material they contain, and provides for education and training. Applying the Biosphere Reserve concept to the sea remains a very great problem. In this paper I will examine this problem in very broad terms.

Several central questions are important: (a) how may the functional units, or ecosystems, of the sea be identified?; (b) how may core areas, or what may be called critical habitats, be described and protected?; (c) how may we learn to recognize buffer areas, those places where essential processes for the stability of the core take place?; and (d) what research plans and methods are appropriate, especially emphasizing process studies? These are very large questions. Some answers are at hand for terrestrial and some coastal areas, but very few for the vast hydrospace we call the sea. Nevertheless, it is fortunate that the U.S. and U.S.S.R. are united across one area, Beringea where, perhaps, these questions may be productively examined. This area is now mostly sea, comprising the Bering and the Chukchi seas. Not very long ago, it was mostly land, forming a terrestrial migration route between the Nearctic and Palearctic Realms. It is an area of common resources and common native peoples and languages. It is, however, under a complex of national and international jurisdictions, even being a "commons" in many of its aspects.

To attempt answers to the above questions is somewhat presumptious; but for heuristic purposes, let us suppose that the functional unit is Beringean Shelf itself. There is some good evidence for this assumption. Hood and Kelly, eds. (1974) and Takenouti and Hood, eds. (1974) present summations of knowledge about the southern portion of the region, about which most is known. The questions related to core areas and buffer zones can only be answered cursorily in light of present knowledge, but certain areas of interest are examined

below in the perspective of the Biosphere Reserve concept. The fourth question must be answered taking into account the great difficulties of logistics in seasonally ice-covered seas. These are the only seas for which neither of our nations, to the best of my knowledge, has all-season oceanographic ships. Thus, at-sea research and ground truth for aerial or other methods is a very real problem.

Two major considerations loom at the outset. First, the "commons" and various jurisdictional regimes for the sea raise difficulties. The Law of the Sea, as currently defined, is not in accord with ecological reality, nor do mechanisms exist for the creation of reserves in international waters. Hedberg (1976) states, in considering newly proposed 200-nmi (360.4-km) limits, that such reserves "lack any basis in nature and logic." Hedberg considers petroleum resources in making his statement; but for living resources, such limits are even less sound ecologically than they are for minerals. He proposes, for example, a "continental margin boundary guide," in which case there would be no boundary between our nations, which might be a useful outcome of the "marine revolution" (Ray 1970). Of course, the point here is not to examine marine law, but to comment on the present impossibility of unilaterally setting aside representative samples of ecosystems and biotic provinces outside territorial waters. This does not mean that we should not establish Biosphere Reserves there, only that we must do it jointly, paying perhaps lesser attention to core and buffer boundaries than to the compatible and sustainable impacts of our activities.

The second consideration has lately been expressed for MAB by Dolan, Hayden, and Heywood (1975). Legally, and in the minds of many, the oceans' high water mark is most often a boundary between two systems. The reverse, however, is true; this line unites the two realms because of the dependency of both oceanic and terrestrial organisms on the coastal zone. The coastal zone, in both aquatic and terrestrial aspects, is a transitional zone, or ecotone, and comprises some of the most dynamic physical and biological environments. An analysis of the coastal zone involves recognition of aquatic and terrestrial physical and biological processes. It may be said, with considerable justification, that all of Beringea is a coastal zone, particularly if we take Pleistocene history into account.

Ray and Dasmann (1976) have recommended an approach to the establishment of Biosphere Reserves in marine environments. Acknowledging our ignorance of the sea, we state "...we must not await the accumulation of complete knowledge - an impossibility anyway - before taking significant action." We point out essential differences between terrestrial environments and those of the sea, among which are the size of the ecosystems, the mobility of marine organisms, the three-dimensionality of the hydrosphere, and "sink," "downstream," and "short circuit" effects. We point to habitats as being reflective of ecological processes and conclude: "given that we do not understand ecological processes well enough to be able to predict the effects of man's perturbations; given our desire to protect the integrity of nature; given that marine and estuarine systems are too large to protect by means of reserves in their entirety; given that

the existence of a diversity of biotic provinces, habitats, species, and cultures of man, is probably reflective of ecosystem processes in all their complexity; therefore, let us set about assuring that diversity in all its aspects is represented in protected areas for the principal reason of understanding those processes and formulating procedures for man's actions which will neither jeopardize them nor - in the long run - man himself."

I can think of no area more appropriate to this objective than Beringea.

DESCRIPTION

Beringea is shown in figure 1 and consists of the shelf area of the Bering and Chukchi Seas, bordered on the north by the Arctic Ocean Basin and on the south by the deeper waters of the southwestern Bering Sea which forms in most ways, a northward extension of the Pacific Ocean.

First and foremost, the area is immensely productive and rich in terms of both renewable and non-renewable resources. It is essential that resources be exploited compatibly, and particularly that non-renewable resources not be exploited so as to jeopardize the renewable ones. I cannot think how the reverse could take place. But the immediate, short-term gain from exploitation of oil and gas, for instance, is so immense that one can quickly lose sight of the fact that fisheries and other living resources are more valuable in the long run, as they are theoretically infinite, given time. Nevertheless, conflicts have arisen and will intensify. Figure 2 illustrates one such conflict and also presents a strong justification for the establishment of Biosphere Reserves in the region as a matter of highest priority.

The Beringean region is at times temperate and at times arctic; this factor is essential in comprehension of it. Sea ice cover, shown in figure 3, actually increases total annual production because its presence is a major factor in two primary productivity periods--late winter to early spring and late spring to early summer. McRoy and Goering (1974) have summarized information on the mechanisms involved. Winter primary productivity derives both from algae which live on and in the sea ice and from the water column, meaning that winter production is high in contrast to many oceanic regions. Summer primary productivity rates are among the highest of any ocean, those of the Bering Strait region rivaling oceanic upwelling systems. New calculations tell us that sub-ice algae contribute about 9 percent of total Bering Sea annual primary production, but this figure is somewhat deceptive as there is a significant contribution from the presence of sea ice itself. The algal bloom in the ice is but part of the picture. There is also a bloom in the wake of the retreating spring and summer sea ice which "is apparently promoted by stratification of the water column from melting ice." McRoy and Goering further state: "Because of the seasonal ice cover the total annual production of the Bering Sea is considerably enhanced. Furthermore, the annual spring increase begins in the middle and northern waters instead of the usual southern."

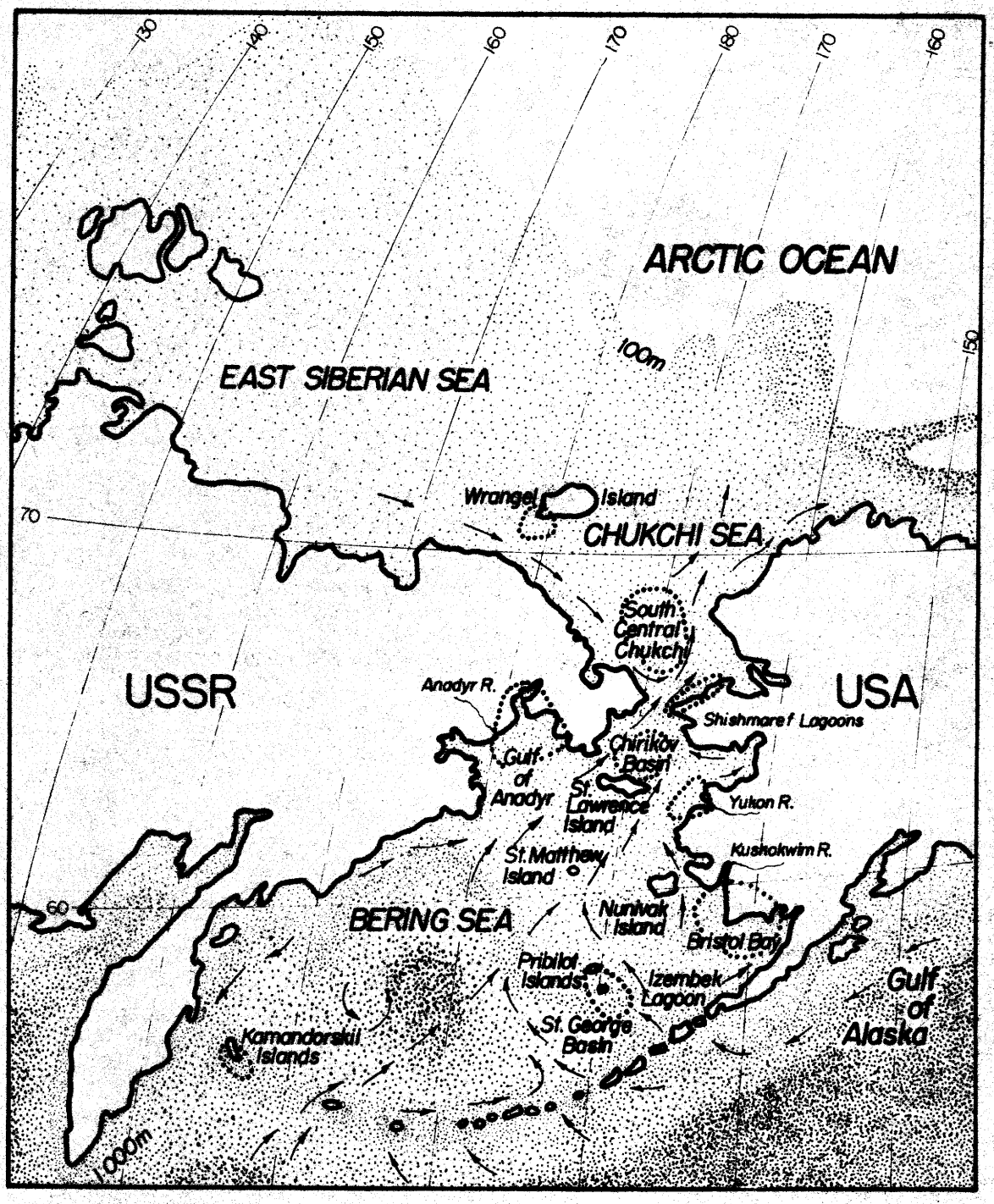

Figure 1.—Beringea and its proposed Biosphere Reserves.

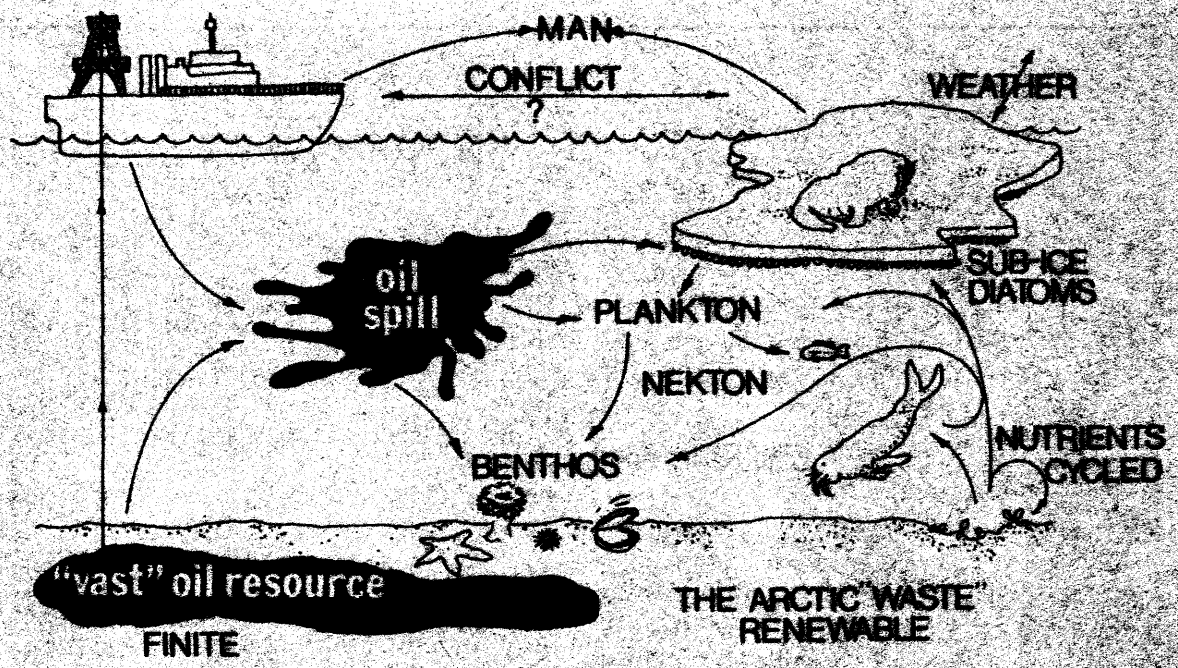

Figure 2.—Potential conflicts which may arise from man's requirements for the living and non-living resources of Beringea. The popular conception of an Arctic "wasteland" ignores the huge living resource of the region and the fact that it is renewable. Oil threatens benthic fauna, subice diatoms, plankton, and the integrity of sea ice and its role as a determinant of northern climate. (After C. G. Ray and D. Wartzok 1974.)

Two other major sources, rivers and lagoons, contribute to total production. The flow volume from rivers in the U.S.S.R. is about 104 km^3 annually, or about 25 percent of the total. Alaskan rivers, particularly the Yukon and Kuskokwim, contribute about 308 km^3. Rivers bring in sediment, nutrients, and certain pollutants, the latter so far in relatively small amounts. Lagoons are the other major source. Their tidal exchange rates are equivalent to major rivers; and one of them, Izembek on the Alaska Peninsula, is perhaps the largest eelgrass (*Zostera*) bed in the world and may contribute 10 percent of the total flow from all lagoons of the Bering Sea (McRoy and Goering, 1974). Its annual production is 3×10^5 metric tons of vegetation, perhaps a third of which is transported to the sea, or 1×10^5 metric tons, meaning that the total contribution from all lagoons to the Bering Sea is 1×10^6 metric tons. Barsdate, Nebert, and McRoy (1974) state that Izembek's annual production is: 16 600 metric tons (t) in particulate carbon, as organic matter important in the detritus cycle; 7 400 t nitrogen; 1 660 t phosphorus; 3.45 t copper; and 386 t silicon. It is quite obvious from these figures that riverine and lagoon habitats are prime sites for the creation of Biosphere Reserves. A good part of the nutrition of the region depends on them.

Ice is also implicated in the ecology of marine mammals and birds which are so dominant in Beringea. Far from impeding the distribution of marine mammals, sea ice aids some of them. Fay (1974) notes that

Figure 3.—Satellite photograph of Beringea—13 February 1973.

sea ice provides marine mammals substrate for rest and to bear young. The need to find access to water dominates their lives and is a major reason why birds are not found among winter sea ice to the extent that some marine mammals are (birds are not able to make holes in sea ice for access to water). Hood, ed. (1974) notes that there are 25 marine mammals species found in Beringea, most of them part-time. Prorating them for the Bering Sea in terms of full-time residents only, there are about 1.5 million individuals, comprising 450 000 t. They may consume 9-10 million t nekton, plankton, and benthic organisms annually. This is about a million t in the form of carbon. The walrus is an example for which more precise estimates of annual consumption are possible than for other species. Based on: (1) a total Bering Sea primary production of 274 million t of carbon; (2) a minimum population of about 125,000 walrus, and a 5 percent of body weight daily food requirement; and (3) a 27-percent conversion rate between trophic levels, it may be calculated that walrus require about 1.1 percent of all the carbon available to all primary carnivores. Evidently, walruses require about 220 000 t carbon, or a fifth of the total required by all marine mammals of the Bering Sea. Hardly any of these mammals, not even walruses, are primary consumers, for all or part of the time. Secondary consumers need four times as much carbon in terms of primary productivity, so that the total requirement of all marine mammals could be as much as 20 percent of the total carbon available to consumers.

Birds and fishes are also exceedingly numerous in the region. The Bering Sea supports one of the world's greatest fisheries. When all of these requirements are considered together, the immediate need is to clarify the very tentative figures on utilization and to achieve a predictive basis for measurement, for there is a clear conflict between man's fisheries and the needs of marine mammals for sustenance. Maximum yield to man's fisheries will surely impinge on marine mammal food availability, and perhaps already has in the case of the fur seal's (*Callorhinus ursinus*) lowered recruitment rates (Ray and Norris 1972). The point here is that one cannot achieve both maximum yields of fishes and maximum yields or even maximum protection of marine mammals and birds at the same time. Regional management, or ecosystem management, is required; and this will in turn require regional research and monitoring.

Turning to non-living resources, Hedberg (1976) points to the great non-renewable resource of the region, petroleum. Among the conditions conducive to its presence are a rich source of the right kinds of organic matter, adequate blanketing of sediments (1 000 m or more in depth , and proper accumulation traps. These conditions are met very often on continental margins; many offshore fields are now located on such uplifted margins. The Beringean region has very thick sediments, to 10 km for the Bering Sea and to 6 km for the Chukchi Sea, and the potential for petroleum exploitation is excellent.

On the other side of the coin, Campbell and Martin (1973) have pointed to the great hazards involved in oil spills under sea ice. Only a slight reduction in albedo, which occurs when oil works its way to the ice surface, causes a significant reduction in ice equilibrium thickness. A 20-percent reduction in albedo can cause

thick Arctic sea ice to disappear in 2 years. Three dispersal mechanisms spread oil about, under, and among sea ice--lead-matrix pumping, oiled hummuck melting, and under-ice transport in the form of oil-water emulsions. Therefore, oil disperses widely, at the same time being degraded very slowly and being practically inaccessible to cleanup in these environments. Campbell and Martin did not consider biological effects; but for primary productivity and for such animals which use sea ice for hauling out, the implications of a spill appear obvious.

AREAS

It is widely acknowledged that a classification scheme forms one basis for the inclusiveness of a reserve system. In this case, there are two such applicable schemes, that of Uvardy (1975) for terrestrial systems and that of Ray (1975) for coastal and marine systems. Beringea is bordered, according to Uvardy, by Alaskan Tundra of the Nearctic Realm and by High Arctic Tundra and Low Arctic Tundra of the Palearctic Realm. My scheme is tripartite. I first place Beringea within two zoogeographic regions: the Temperate North Pacific/Boreal-Arctic for the Bering Sea and the Polar Arctic for the Chukchi Sea. Second, in an attempt to classify coastal regions, I have followed wide practice in identifying Beringea within the Pacific Subarctic-Arctic Biotic Province with Ice-Stressed Coasts. The third part of the scheme is habitat classification, and there are several habitats from exposed to protected, to lagoons and estuaries, to sea ice and water bodies, and to the benthos. Obviously a great deal of modification and study will be required to give these schemes workability of unity of approach, as well as credibility in terms of uniting land-and-sea coastal ecotones.

The areas of interest described below are not meant to be inclusive, nor do they describe ecosystems. Rather, they are "hot spots" for our activities, places where great productivity occurs, places from which nutrition important for the Beringean region emanates, places where conflict is occurring or will occur and where monitoring is especially important, or places where man's history in the region may be recorded in terms of underwater archeological sites. All are identified in figure 1.

The sites may be broken down according to type, but I prefer not to do so at present as some of them serve multiple purposes. They are, approximately from south to north:

1. *Aleutian Islands.* To my knowledge, this is the only Biosphere Reserve proposed for the region. It is an island site and not really a part of Beringea, but forms an important interface with the North Pacific.

2. *Kommandorskii Islands.* As the place discovered by Bering and where the last Steller Sea Cows existed, this site has both historical and biological interest. It is an Aleutian extension, geologically, and is not a part of Beringea, but supports a large herd of Northern Fur Seals, *Callorhinus*, which interact with those of the Pribilofs, so it should be considered.

3. *Pribilof Islands - St. George Basin.* This area supports the largest Northern Sea Lion herd in existence as well as being a major fisheries region. It has petroleum potential. Its waters may contain archeological material.

4. *Izembek Lagoon.* The value of this lagoon is given above.

5. *Northern Bristol Bay.* This is an area of intense fisheries interest. It includes the drainage from several important rivers which are spawning grounds for important commercial and non-commercial fishes. Its primary productivity may be very high, but it has a rather low standing stock of benthic organisms, possibly because of predation effects.

6. *Kuskokwim Delta.* The value for production has been discussed above. In addition, the delta supports vast waterfowl breeding grounds.

7. *Nunivak Island.* There may be archeological remains in its nearshore or offshore waters.

8. *Yukon Delta.* The same may be said for this area as for the Kuskokwim.

9. *St. Matthew Island.* The area is a possible archeological site.

10. *St. Lawrence Island.* Many archeological sites exist on land. There may be some underwater as well.

11. *Anadyr Delta.* This is the third largest river emptying into Beringea and contributes valuable nutrients.

12. *Chirikov Basin.* South of St. Lawrence, the benthic standing stock is 100-200 gm/m^2 in wet weight. North of St. Lawrence, the figure jumps to 1 000 gm/m^2. The explanation may lie in Yukon-Kuskokwim-Anadyr contributions in nutrients which flow north to the Chirikov Basin. This is an important feeding area for many marine mammals, including summer populations of the grey whale (*Eschrichtius robustus*).

13. *South Central Chukchi Basin.* The benthic standing stock is even higher here, to 1 000-3 000 gm/m^2 wet weight. This is probably because of a "river mouth effect"; that is, nutrients and particulate matter fall out of the water column as water current velocities decrease north of the Bering Strait. It is inherent that the Bering Strait itself be considered in studying this region. The region is to date almost unexploited and supports the bulk of summer grey whales. It has very high petroleum potential.

14. *Shishmaref Lagoons.* These are not nearly as well known as Izembek; but by analogy, we can estimate their importance to the region.

15. *Wrangel Island.* The entire island is important but is particularly so for marine animals and birds. The most important walrus summer hauling out ground in the Chukchi Sea occurs there on Cape Blossom. The surrounding region is very productive as well. These are but brief sketches, each of which deserves a paper in itself.

They are only a first attempt to suggest Biosphere Reserves for Beringea. Want of knowledge of the U.S.S.R. side has impeded my efforts somewhat.

RESEARCH AND MONITORING

Research and monitoring are really two aspects of the same thing; the essential difference being that research seeks to identify essential key data and processes and to form stochastic models to be used as bases for long-term guardianship, which we may call monitoring and by means of which we may keep a watch on our own perturbations. In the case of Beringea, critical problems and conflicts are arising so rapidly that protection, research, and monitoring must evolve together. I can give only the broadest outline here, based in large part on the difficult logistics problems mentioned above.

There are three kinds of surface-based logistics which come to mind:

1. Land Stations. Several sites exist where data may be gathered from shore. These may not include laboratories at present, but the sites could easily be so amplified. Many native villages exist, for example, where scientists have worked on population or environmental problems.

2. Ships. A ship might be assigned as a long-term commitment to MAB. In fact, there is little alternative to ship-based activities for many of the sites listed above.

3. Remote Stations. Modern technology has given us many ways to look at the environment and to quantify what we often cannot see; side-looking radar is one, radio tracking of living organisms is another. Movements of ice and its structure and the movements of marine mammals or birds, for example, may be recorded without man's attendance and the data either stored or transmitted in real time to data-collection sites via satellites.

Obviously, none of these technologies give the sort of coverage and resolution we need over the ice where few, if any, ships venture on any but a very short-term basis. Remote sensing is the only alternative available:

1. *Visual surveys.* These have been conducted by both of our countries lately in conjunction with the Marine Mammal Project of the U.S.-U.S.S.R. on cooperation in the field of environmental protection. Visual or strictly observation surveys have major faults in terms of quantification, but they are useful for descriptions of biotic distribution and some superficial descriptions of biota and habitat.

2. *Aircraft remote sensing.* Aircraft such as NASA's Convair-990 and its NP-3, as well as those of the U.S. Geological survey, have been flying over Beringea since 1973 taking part in BESEX, the U.S.S.R.-U.S. Bering Sea Experiment, AIDJEX, the Arctic Ice Dynamics Joint Experiment, BESMEX, The Bering Sea Marine Mammal Experiment, and projects of the Outer Continental Shelf Energy Program. I am not sufficiently aware of Soviet activities in remote sensing to mention them. Radar, laser profilometry, microwave imagery, infrared imagery, and visual spectrum photography are now developed to the extent that quantification and description of habitats and certain biota within them are possible in ways that visual methods cannot match. Ground truth for these methods, however, remains a problem because of the inaccessability of many areas.

3. *Satellite remote sensing.* In no other way is such a broad environmental perspective possible. Figure 3 shows Beringea in mid-winter 1973. Resolution obtained by satellite methods is on the order of 30 - 1 000 m, according to which satellite and which spectra are being used. Ground truth is a problem, as for other remote sensing methods. I have so far mentioned only logistics. Objectives for research include:

a. Habitat description;
b. Dynamics of river and lagoon effluent;
c. Ocean dynamics;
d. Food web and trophic analysis;
e. Assessment and population studies;
f. Effects of man's harvest on the ecosystem;
g. Pollution;
h. Physical effects of exploitation;
i. Effects of "civilization" on traditional cultures; and
j. Adaptation, physiology, and behavior of selected "target," "sentinel," or "keystone" organisms.

These 10 are hardly inclusive; nor perhaps should they be. It is important that research in Biosphere Reserves be highly selective, emphasizing process, target species, and target questions. It is not necessary to incorporate all phases of research, but it is important to identify research according to well-worked-out theoretical process models or stochastic models derived from known data.

I would like to select one example of the sort of thing I have in mind, namely BESEX. The Joint U.S.S.R. and U.S. Bering Sea Experiment. Its structure was worked out by means of working groups and/or task forces. A large scale, joint expedition resulted in 1973, involving ships and planes of both our nations. A symposium followed (Kondratyev, et al., eds. 1975) in which data were presented in detail only a year following the experiment. BESEX forms a model for us, and I dare say, for other activities of MAB and the U.S.-U.S.S.R. Agreement on Cooperation in the Field of Environmental Protection.

CONCLUSION

I propose that we take the BESEX approach in evolving marine and coastal programs for Beringea. The immediate problem is to compose a Task Force to define the program in detail; that is, to first identify Biosphere Reserve areas and logistics for the work and to evolve suitable methods directed towards a high-priority list of target questions. This must be a long-range program; but it should have regular review, perhaps annual, for continual data-exchange and reexamination of objectives. It must be flexible while being concrete and pragmatic.

Second, the legal and jurisdictional aspects of Biosphere Reserve establishment for the coasts and seas must be examined. The Task Force must look into this as a matter of some urgency. There need not be the implication that such reserves eliminate man's activities over wide ocean space, but that certain core areas of limited size be so exempted and that man's activities throughout be in accord with the Reserve's stability, to the best of our ability to set guidelines. This involves the evolution of a preliminary management plan based on present knowledge.

Third, we need to develop a habitat classification scheme for Beringea so that representative habitat types may be included in Biosphere Reserves. Existing schemes for land, coasts, and seas are not ecologically compatible. Perhaps satellites, with an adequate "ground truth" program, can help in this large task.

Fourth, we must not omit research and monitoring of animal populations and I strongly suggest using birds and mammals as indicator species as they appear above the air/sea interface and can be remotely sensed, visually or otherwise. Remote sensing, however, gives only part of the picture. Radio tracking is the only present technology for monitoring individuals and/or populations semi-continuously. Strategic positioning of land stations for tracking radio-tagged animals could be of immense benefit. The technology for this is rapidly becoming available.

Fifth, native groups must be involved in this work. Beringea is united by common cultures which are themselves threatened and which have been effected severely by civilization over the past 200 years. We cannot reverse matters, but we can seek involvement of natives for the purpose of determining wants, needs, and values.

What I have suggested is ambitious in the extreme, but I see no other way to handle this subject. We cannot delude ourselves that by setting limited areas of sea aside we protect ecosystems, nor that our knowledge is better than marginal. Beringea itself is, in a large sense, a Biosphere Reserve candidate in its own right. We must see our chore as identifying core areas within it for specific, local protection and study which relates to the whole. Sullivan and Shaffer (1975) note that the "strategy for locating... reserves involves consideration of their location, number, size, and linkage. The equilibrium theory of island biogeography is a useful analytical tool for predicting future biogeographies

according to the dynamics of present plant and animal distributions." Thus, we seek not to locate or create islands within Beringea which cannot remain diverse or stable, but to see where the linkages are and, by protecting them, protect the region as a whole while we use and enjoy it.

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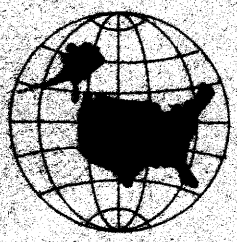

The Role of Biosphere Reserves in the Management of National and International Ecosystems

by

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INTRODUCTION

Although all periods of history are unique and interesting for various reasons, the present period is especially interesting because of the apparent conflict between environmental concerns and developmental needs. The past decade has witnessed a growing awareness of the need for and desirability of clean air and water, of energy development and conservation, of soil productivity and maintenance, of population stabilization, and of wildlife conservation and habitat protection. At the same time, we have demanded continuing supplies of inexpensive energy, increased industrialization, more money, and more mobility. At first, we wondered if industrialization and environmental integrity were even possible; perhaps one had to be sacrificed for the other. We now recognize that both are possible, and necessary.

ECOSYSTEM MONITORING

The need to monitor and document the changes in national and international ecosystems which will occur in the resolution of the present development-environmental conflict is of increasing importance. Biosphere Reserves represent a new and unique method of responding to this need. Such reserves are necessary not only in preserving or protecting natural areas and associated genetic material, but also as centers for scientific research and educational programs. It is extremely important that such Biosphere Reserves encompass all major ecosystem types, whether national or international in scope, and whether pristine or man-influenced. Only from such a diversity of areas can accurate monitoring of all environmental impacts be accomplished.

Biosphere Reserves are located throughout the world and can generally be described as land, coastal, or aquatic environments or ecosystems which contain representative examples of natural biomes or habitats which are protected so that they can be maintained for future generations. While this is a description of what they are, the question remains, what do they do? What is their role in the management of national and international ecosystems?

THE ROLE OF BIOSPHERE RESERVES

In my judgment, Biosphere Reserves should have four basic roles. First, they should be an integrated part of an interdisciplinary, worldwide program. Even though under the protection and control of a sovereign State, the reserve should not be maintained for the exclusive use of scientists from the sponsoring State. Nor should the reserve be dedicated to the study of only one factor of the environment. The Biosphere Reserves should be parts of a whole, parts of an entire and cohesive system, where individual but coordinated conservation and research activities by international scientists from all disciplines of environmental science can proceed. Biosphere Reserves will also serve as genetic pools designed to preserve the diversity of plants and animals essential to the preservation of life support systems.

The second basic role of Biosphere Reserves is to provide baseline data for measuring intrusions into the environment. Although it is certainly admirable to study ecological relationships and measure environmental impacts, such data have little meaning without knowledge of the original relationships or the undisturbed environment. Once these baselines have been determined and recorded, it is possible to assess present environmental conditions and predict with greater accuracy the probable environmental consequences of resource decisions or habitat manipulations.

The third role is to use the Biosphere Reserves as a platform for the development of an international monitoring system similar in design philosophy to that suggested by the Global Environmental Monitoring System (GEMS). Although the environmental monitoring program envisioned for the Biosphere Reserves is more comprehensive than that suggested for GEMS, the program parts are similar and include monitoring, research, evaluation, and information exchange. These steps are essential in the establishment of a practical and efficient system. The GEMS system also calls for the establishment of data banks at national, regional, and world levels. Such data banks would also seem valuable and worthwhile for the Biosphere Reserve monitoring system. The Biosphere Reserves should provide a coherent, integrated source of baseline data and information for determining long-term trends and environmental impacts. National facilities could concentrate on the analysis of data collected as part of the reserves monitoring programs. The regional facilities could analyze and store data concerning environmental changes of regional or multi-biome concern. The world facility could assess world environmental conditions, develop reports and reference materials, and provide a location for training and education programs.

The final basic role of Biosphere Reserves is to monitor changes in the global environment. This function could be handled in large part under the world facility just described. It would be the responsibility of individual reserves to monitor environmental conditions in a coordinated and integrated manner so that comparable data are available globally. Only in this manner can similar biomes

and ecosystems in different parts of the world be monitored and compared in a comprehensive and meaningful fashion.

MONITORING BIOSPHERE RESERVES

In this regard, I would like to describe an environmental monitoring system implemented by my organization, the National Wildlife Federation. The National Wildlife Federation's Environmental Quality (EQ) Index is an effort designed to provide the concerned citizen with a comprehensive review of published information on factors affecting environmental quality presented in rather simple language and graphics readily understood by the masses. We are not so foolish or short-sighted as to think that our Index represents the ultimate product or even the best analysis of available data. We do feel, however, that it gives the average citizen a much better grasp of the environmental situation as it exists today and as it might look tomorrow, next year, and in the foreseeable future.

The EQ Index is the end product of an exhaustive, scholarly exercise that attempts to reduce reams of information--much of it disjointed, at best, and some possibly erroneous at worst--into a simple, orderly, graphical representation of environmental conditions. When first published in the fall of 1969, six natural resources were evaluated in the EQ Index: air, water, soil, forests, wildlife, and minerals. In 1970, a seventh item--living space--was added to the list. These categories of the environment were subjectively rated from Best to Worst on a scale of 0 to 100. An "0" would equal death or disaster; "100" would be ideal conditions with environmental equilibrium. For example, soil is, in our relative judgment, in the best condition of any single resource; but soil conditions are still far less than ideal. In 1970, it was given an Index of 80, but this year, because of continuing losses, the rating slipped to 73. Air represents the worst category of the environment. It actually poses a danger to human health in many cities. The 1970 Index was placed at 35, fell to 33 in 1972, but has improved in 1975 to be rated at 35.

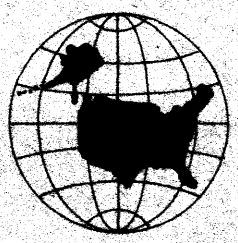
Quite obviously, a number of value judgments were arbitrarily made. These, in turn, lead to the conclusions presented in the EQ Index. Our judgments and conclusions are necessarily subjective; and while we consider these judgments scrupulously fair, they are subject to challenge. We believe that with experience and additional data, they will become more accurate. In fact, we hope the scientific community, possibly through a Biosphere Reserve monitoring system, can help in eliminating those judgments which have insufficient backup data by filling in the gaps in our body of knowledge about the biosphere in which we live.

SUMMARY

The scientific community has an obligation to assist our decision-makers in choosing between a denaturalized, defiled, and debased

existence or a new birth of quality living complete with the preservation of objects of great natural beauty and esthetic appeal in addition to the restitution and rehabilitation of those renewable natural resources upon which life is dependent. There are those who say science, in an ever growing industrialized, mechanized, and computerized society, is incapable of providing the technology to clean up our polluted planet. I say the capability is there but the willingness to devote the time, to pay the price, to establish objective standards of enquiry, to identify pollution abatement as a high priority domestic and world problem is lacking. The Biosphere Reserve program is a good first step in the right direction and will become symbolic of the determination of world leaders to know more of the effects of man's intrusion into the environment.

The professional resource manager should immediately embrace an advocacy role in environmental affairs. The scientist should no longer be content with publishing the methods and conclusions of a research effort or handling his working assignment. In this modern day of better education and an ever expanding body of knowledge, the cool, calculated, objective, and expert voice of the true scientist is badly needed in molding international public opinion in the proper form and in formulating guidelines that will direct our international policy toward an improved natural environment and a quality life style for all the people of the world.



Management of Experimental Reserves and Their Relation to Conservation Reserves: The Biosphere Reserve Cluster

by

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INTRODUCTION

The goals and objectives of an international network of Biosphere Reserves [UNESCO[3] Program on Man and the Biosphere (MAB), Project No. 8] are diverse. Major themes include (1) the conservation of representative and unique environments, (2) research emphasizing environmental monitoring under natural conditions, (3) research exploring the impact of anthropogenic factors on natural ecosystems, and (4) education. Historically in North America, most individual reserves have been established with only a subset of these goals in mind. With existing institutions and a great diversity of ownership patterns, program objectives, and site histories, a single reserve rarely provides the facilities and resources necessary to address all the aforementioned goals.

A major conflict at single-purpose reserves is the frequent incompatibility between the conservation and manipulative research objectives of the MAB program. Hence, protected core areas and peripheral buffer zones were proposed (MAB Task Force 1974) to resolve the conflict between different types of reserve utilization. These zones were drawn as being contiguous in space (fig. 1a). Because contiguous buffer zones available for manipulative studies do not occur around all conservation reserves, an extension of this concept, called the Biosphere Reserve Cluster (fig. 1b), was proposed for the United States by a committee of Federal agencies. Here, the research on human

[1]Research sponsored by Union Carbide Corporation under contract with the Energy Research and Development Administration.

[2]Publication No. 856, Environmental Sciences Division, ORNL.

[3]United Nations Educational, Scientific, and Cultural Organization.

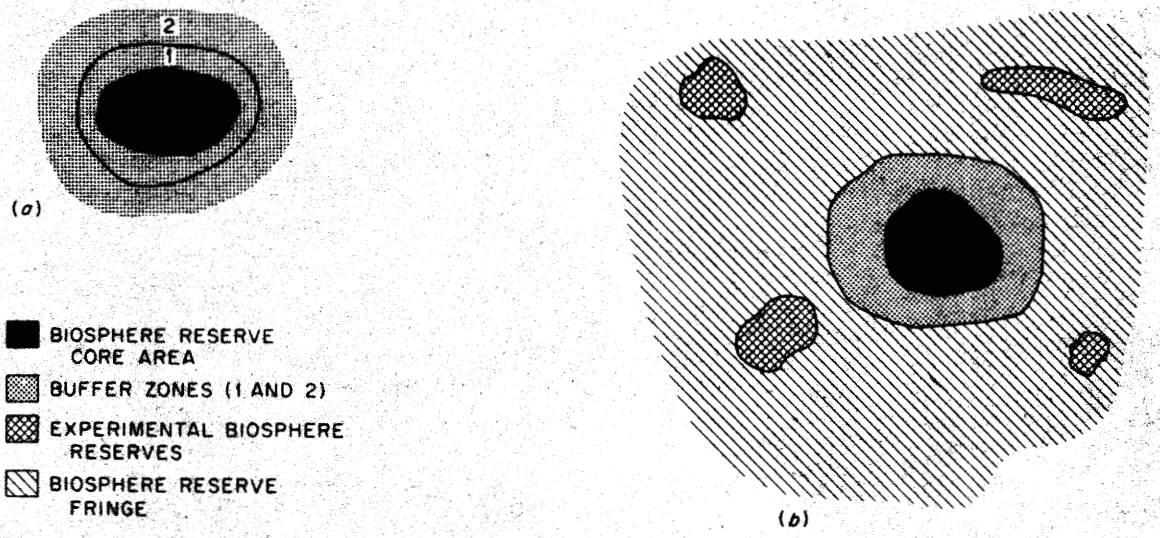

Figure 1. (a) Generalized Biosphere Reserve showing the core and buffer zone concept as suggested by MAB (1974). No development is permitted in the core area, and uses are strictly controlled. Buffer zones are used for research and education purposes, and public use is limited. Manipulations could be carried out in buffer zones, most appropriately in buffer zone 2. (b) Diagrammatic representation of a Biosphere Reserve Cluster. Core-buffer zone concept is extended to include geographically separate reserves which can provide the opportunity for controlled manipulations while also better representing regional variability. Contiguous buffer zone may or may not be present. Fringe areas are shown between and surrounding the reserves.

impacts proposed by the MAB committee for the buffer zone would frequently be conducted at separate but nearby experimental reserves which occur frequently within all the major biomes in the U.S. In this concept, a central conservation reserve forms the core of the Biosphere Reserve Cluster, with a contiguous buffer zone (where available) and with nearby experimental reserves fulfilling the manipulation research objectives. Thus, the cluster of reserves, together with fringe areas needed for future or supplementary studies, can fully address the goals of a Biosphere Reserve network and at the same time can remain compatible with the existing land-use patterns and agency responsibilities.

RESERVE TYPES AND INTER-RESERVE COMPARABILITY

Conservation-Oriented Reserves

Most conservation reserves have been established to preserve unique landscapes and biota. Another major purpose is recreation. Research programs carried out in conservation reserves are usually directed towards the study of natural phenomena, including biological inventories, habitat descriptions, and monitoring of background

conditions in pristine environments. Although investigations of man's impact on the natural environment are carried out in these reserves, they are primarily related to the effects of public use (i.e., recreational development). Manipulations necessary to study more severe environmental impacts such as land-use change, timber harvesting, and corridor construction (highways, power line rights-of-way) are prohibited or limited by law. For research on landscapes and human effects under controlled conditions, groups of nearby experimental reserves are necessary.

Experimental Reserves

In the United States, there are large numbers of experimental reserves operated by a variety of Federal agencies, State governments, and private institutions. In general, these reserves constitute the experimental component of natural research laboratories, permitting both comparative research among different ecosystem types and different kinds of man-induced perturbations. The reserves exhibit a diverse array of independent, complementary, and overlapping responsibilities. Many of them compare functionally with reserves in the Soviet Union where manipulations are allowed (e.g., competition studies of V. P. Karpov carried out at the Central Forest State Reserve).

Currently, the many experimental reserves (Parsons 1975) under the jurisdiction of such agencies and private groups are being organized into a network of Experimental Ecological Reserves (The Institute of Ecology 1976). The key objectives of such a network are to:

(1) provide data on a number of ecological processes for a variety of ecosystem types ranging from self-regulated intact systems to those exhibiting the effects of various extreme disturbances,

(2) analyze the changes in ecosystem properties or process rates as the result of planned treatments,

(3) coalesce diffuse research activities and focus individual disciplinary efforts on integrated studies of complex ecological systems, and

(4) provide long-term data and insight on the effects of changing ambient environmental parameters on ecosystems and their constituents.

Sixty-seven research sites have been identified by The Institute of Ecology for inclusion into a national system of Experimental Ecological Reserves. These (1) represent the important ecological assemblages of the U.S., (2) provide accessibility and facilities for long-term research, and (3) protect land and waters for baseline monitoring, experimental controls and manipulative treatments. Point (3) relates directly to the recommendations of a U.S. panel (National Research Council 1976) on the Implementation of the Global Environmental Monitoring System (GEMS). They suggest "...the establishment of a global system of baseline and impact stations, with the former placed so as to represent the world's

major biome types, and with the latter paralleling the areas identified in the agriculture and land-use program [of GEMS]".

The inclusion of Experimental Ecological Reserves in the reserve cluster, as substitutes for or extensions of contiguous buffer areas, is critical to the attainment of the goals of a network of Biosphere Reserves as identified by the UNESCO Man and the Biosphere Program. The opportunity for manipulative, experimental research is their unique contribution to the reserve cluster, collectively representing and achieving the objectives of a Biosphere Reserve.

Intra-Reserve Comparability

A critical factor in the establishment of a reserve cluster relates to the extension of results between experimental and conservation reserves. A fundamental question is whether ecosystem responses following manipulations in nearby experimental reserves are indicative of such rates should they occur in conservation reserves. Optimally, experimental reserves should include tracts which represent regional variability and have many environmental features (e.g., elevation, bedrock types, vegetation) in common with the conservation reserve. Sometimes the conservation reserve can serve as a control for manipulations on nearby experimental tracts. If an experimental tract with the desired attributes is not available for inclusion, studies need to be conducted which can provide for the adjustment of process rates between reserve types. The work of Shanks and Olson (1961) stands as an example of this technique. Decomposition rates of fallen leaves were determined for an environmental gradient running from high elevations in the Great Smoky Mountain National Park to lower elevations at the Energy Research and Development Administration's (formerly Atomic Energy Commission) proposed Oak Ridge National Environmental Research Park. These data enable decomposition rates to be adjusted for elevation (moisture and temperature) within the Southern Appalachian region.

Studies from the full complement of reserves forming a gradient from pristine to heavily impacted can be organized to address another important question, "At what levels of disturbance do ecosystems begin to degrade or recover with unusual slowness?" Given enough variety of conditions in the cluster, the reserves can be aligned to represent ecosystems under a range of stresses. This re-emphasizes the need for variety in both natural and disturbed conditions when selecting reserves for inclusion in the cluster.

SOUTHERN APPALACHIAN MOUNTAIN REGION: EXAMPLE OF A RESERVE CLUSTER

The Great Smoky Mountain National Park, along the Tennessee-North Carolina border, and the nearby U.S. Forest Service Coweeta Hydrological Laboratory are the first cluster components to be officially designated as a Biosphere Reserve. Another nominated

experimental reserve in a neighboring geological province but in the same drainage basin is the proposed Oak Ridge National Environmental Research Park (NERP) of the Energy Research and Development Administration (fig. 2). The National Park represents the conservation

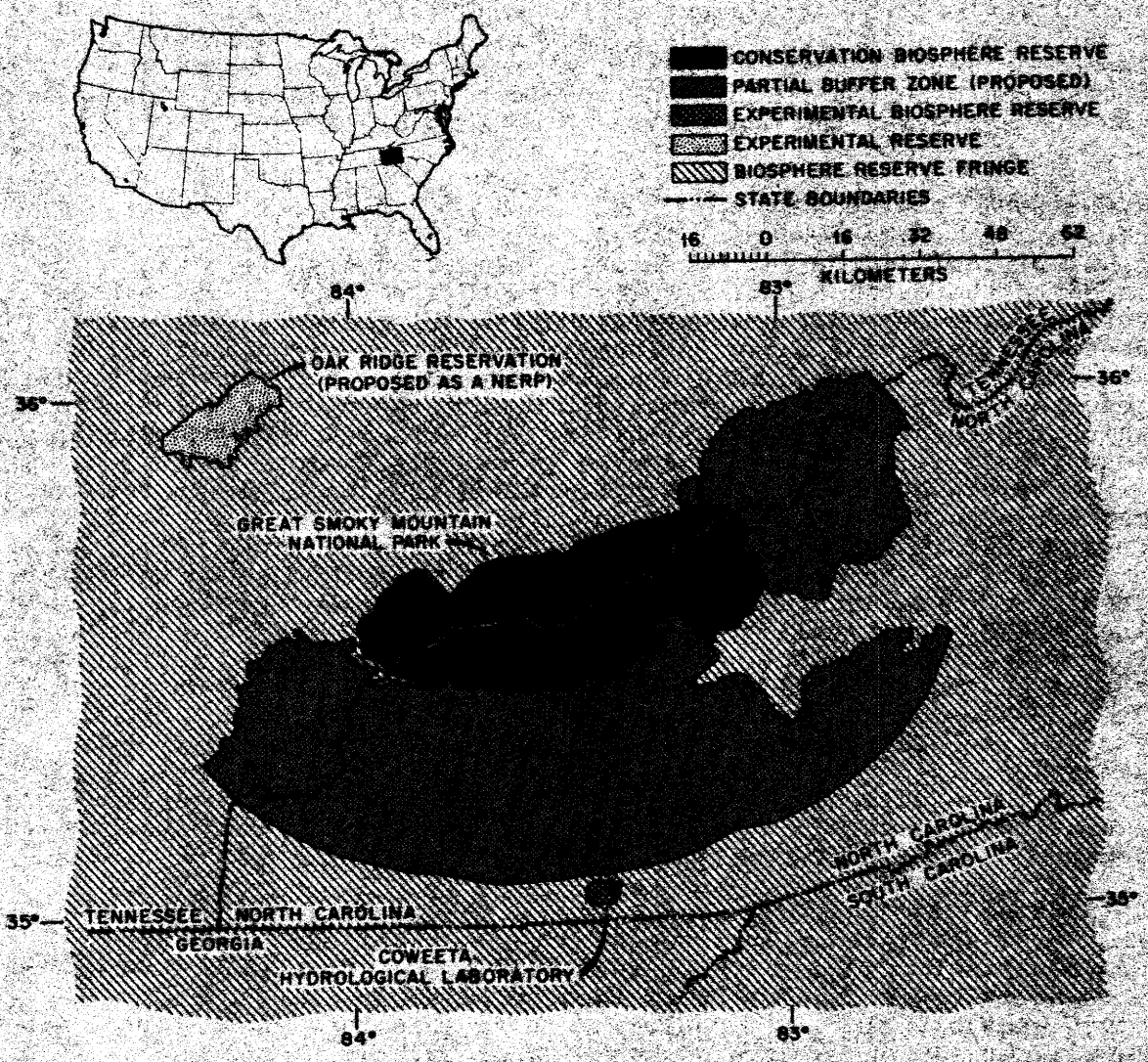

Figure 2. Example of a Biosphere Reserve Cluster from the Southern Appalachian region, southeastern United States. The major conservation reserve is the Great Smoky Mountain National Park. Partially surrounding it is a buffer zone (proposed). Nearby experimental reserves are the Coweeta Hydrological Laboratory and the proposed Oak Ridge National Environmental Research Park (NERP). Fringe areas include additional tracts which can augment studies carried out within the Biosphere Reserve Cluster.

"core area as defined by MAB (1974), and the Coweeta and Oak Ridge sites represent the separate but nearby experimental reserves. This reserve cluster is the example most familiar to us where a conservation area has been used in combination with nearby experimental tracts.

Work already completed within the cluster can serve as specific examples of the objectives of experimental reserves listed earlier.

(1) Provide data on a number of ecological processes for a variety of ecosystem types ranging from self-regulated intact systems to those exhibiting the effects of extreme disturbance.

The National Park Service encouraged experiments on the rate of litter decomposition and mineral cycling in the Great Smoky Mountain National Park for comparison with similar process rates at lower elevations at the proposed Oak Ridge Environmental Research Park (Shanks and Olson 1961, Witkamp and van der Drift 1961). Studies were also designed (e.g., Clebsch and Shanks 1962; Whittaker, Cohen, and Olson 1963; Sollins and Anderson 1971) so that both areas and other parts of the Eastern Deciduous Forest Biome would be represented by a coherent set of phytomass and production data. Rates of ecological processes have also been measured in the notorious Copperhill basin where ecosystem degradation by air pollution has proceeded to an extreme, illustrating one example of severe disturbance and also of some recovery by ecological succession (Witkamp, Frank, and Shoopman 1966).

(2) Analyze the attendant changes in ecosystem properties or process rates as the result of experimental landscape manipulations.

Treatments on several watersheds at the Coweeta Hydrological Laboratory have been assessed by their effect on components of the water budget and mineral cycling patterns (Johnson and Swank 1973). Some catchments have been converted to artificial communities. Results from tree plantations have illustrated changes on a landscape scale e.g., dense white pine (*Pinus strobus*) significantly reduced total water yield (Swank and Miner 1968).

Both Coweeta and Oak Ridge have additional sites which can be manipulated according to future research needs. Coweeta has limited areas committed for indefinite protection, but a large catchment is available for long-term control and comparison with manipulated catchments. The proposed Oak Ridge Environmental Research Park (Reichle 1975) has a number of unique natural areas under protection as well as potential catchments that can be manipulated and monitored.

(3) Coalesce diffuse research activities and focus individual disciplinary efforts on integrated studies of complex ecological systems.

Work completed during the International Biological Program addresses this objective. Hydrological and mineral budget studies at the Coweeta Hydrological Laboratory (conducted jointly by the U.S. Forest Service and the University of Georgia) were compared with those of the Walker Branch Watershed in the proposed Oak Ridge Environmental Research Park (Elwood and Henderson 1975). The latter watershed and nearby forests tagged with isotopes have been utilized for many multi-disciplinary ecosystem studies (Edwards and Sollins 1973; Goldstein and Harris 1973; Reichle, Goldstein, Van Hook, and Dodson 1973).

(4) Provide long-term data and insight on the effects of changing ambient environmental parameters on ecosystems and their constituents.

Collection of data useful for long-term assessments of environmental change requires stable ownership and land-use plans. Monitoring studies at the Coweeta Hydrological Laboratory have been uninterrupted since the mid-1930's. Watershed studies at Oak Ridge are more recent, but still span a period of over 10 years. In addition, a large number of permanent forest plots exist within and between experimental reserves which are re-measured at about 5-year intervals. Similar data have been utilized to project changes in the quality of the land cover over time (Johnson and Sharpe 1976) and to show the effect of air pollution on primary production (Whittaker, Bormann, Likens, and Siccama 1974). The current establishment of permanent plots in natural areas at Oak Ridge will provide the basis for determining additional changes in ecosystem parameters for the future. Finally, scientists have utilized both core areas (serving as controls) and experimental tracts to monitor trace environmental pollutants (e.g., Huckabee 1973).

COORDINATION AND INFORMATION SYSTEM REQUIREMENTS

"The ultimate objective of MAB Project 8 is to attain a coordinated network of biosphere reserves...linked by exchange of information...as part of the MAB Programme".[4] Of course, independent thought by creative individuals and groups is vital to enlarge our sources of hypotheses and organized information. It is equally important to ensure that such information is exchanged and utilized by the teams working at all levels of the Biosphere Reserve network.

Within a reserve cluster, methodology and schedules of measurement need to be worked out to enhance comparability, especially where conservation core areas are used as controls. At the national level, inter-agency cooperation is vital; and frequent bilateral or multilateral contact at the international level can lead to a truly global, well-integrated network of Biosphere Reserves. Thus, it is clear that frequent communication facilitated by a well-designed information system is an essential ingredient for success at all levels.

There are many advantages to having a well-designed information system that provides for the organization of data collected from the reserves, facilitates rapid exchange among scientific personnel working at Biosphere Reserves, and enables rapid updates in regional or global maps of pertinent variables. Several examples of such data base organization come from work completed during the International Biological Program (Reichle, O'Neill, and Olson 1973; Ulrich, Mayer, and Heller 1974).

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[4] di Castri, F. 1976. MAB circular letter 1/76. UNESCO, Paris

One rather simple need for assisting both the scientific and management applications of results from experimental reserves is a more orderly handling of spatial data. For communication purposes, we need maps of locations (e.g., latitude-longitude of research sites, monitoring transects, and boundaries of Biosphere Reserve zones which can be updated quickly. We believe computerized maps will help local groups and eventually help the whole global network to keep more currently informed than would otherwise be possible. For example, once tested locally, results for endangered species and habitat locations (Goff, Stephenson, and Lewis 1975) can readily be extended to large regions or continents (Schreiber et al. 1974) or to a global geodetic framework. Figure 3 shows altitude as well as latitude and longitude for the Appalachian Mountain area, including the Great Smoky Mountain National Park and the proposed Oak Ridge Environmental Research Park. Figure 4 shows primary productivity at the national level derived from statistical relationships between climate and production (Sharpe 1975). Figures 3 and 4 were drawn by computer from data stored by geodetic coordinates.

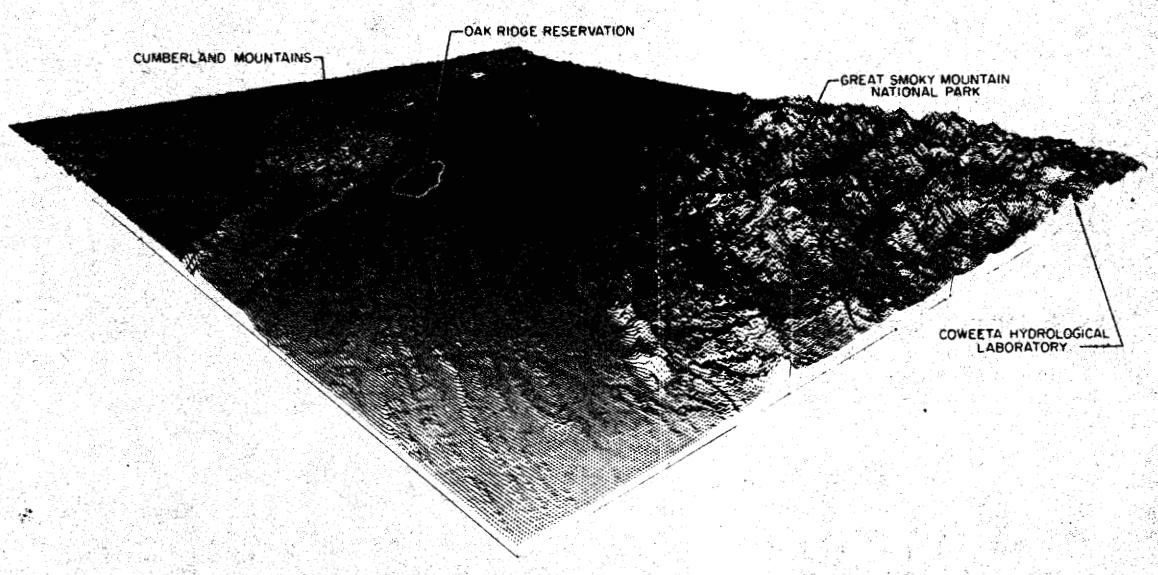

Figure 3. Computer-drawn map (Durfee 1974) of eastern Tennessee utilizing latitude-longitude and elevation data. To the right are the Southern Appalachian Mountains (Great Smoky Mountain National Park and the Coweeta Hydrological Laboratory), in the middle the Ridge and Valley Physiographic Province (proposed Oak Ridge National Environmental Research Park), and to the left the Cumberland Plateau and Mountains.

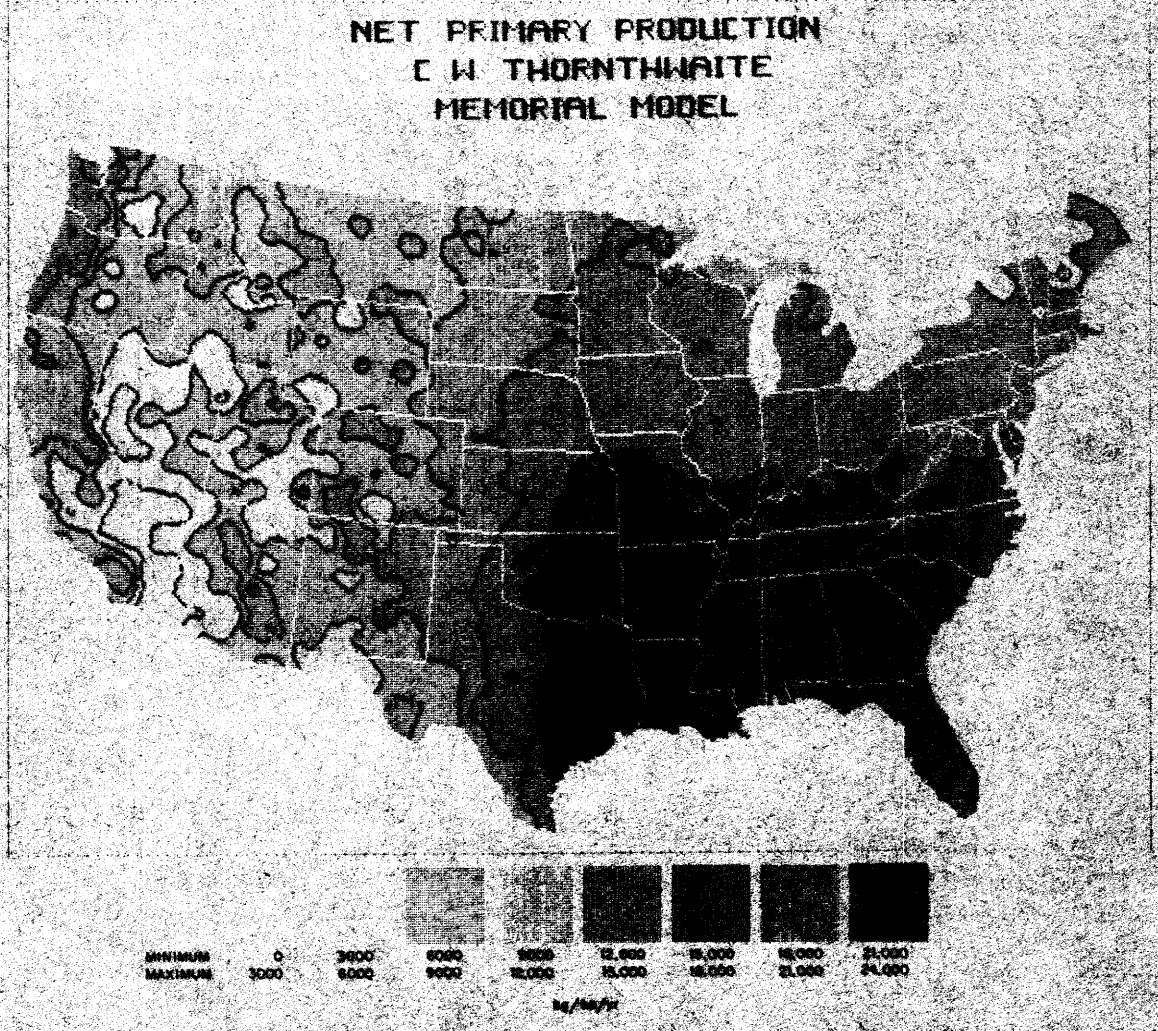

Figure 4. Computer-drawn map of net primary production within the conterminous United States (Sharpe 1975). Values are kg/ha per year, and were derived from a regression of net primary production and average annual water balances.

SUMMARY AND CONCLUSIONS

The organization of the Biosphere Reserve network proposed for U.S.-U.S.S.R cooperation and for broader coordination with UNESCO/MAB illustrates problems which each nation must face in combining conservation with research. The cluster of reserves is proposed as one means to address the diverse goals of the Biosphere Reserve network. The linkage of experimental and conservation reserves will provide information on ecological processes under anthropogenic and natural control. The natural areas under protection with experimental areas

promise to provide better representation of regional variability. Success of the program depends heavily on the active exchange of ideas and information at all levels of the reserve network.

Many of the urgent environmental problems to be solved by experiments and other research are often in locations which are not permanent enough to assure the continuity of records necessary for monitoring the continual changes in the biosphere. The Experimental Ecological Reserve Network will add continuity by providing a coherent set of areas for active research, bringing together the areas, interests, and expertise represented by diverse institutional staffs.

For the synthesis of results, both frequent communication among participants and a well-designed information system are vital. Such an information system should include spatially defined data which will facilitate the use of computers to update maps and other graphic representations of information collected at Biosphere Reserves.

Considerable momemtum is forming in the United States regarding the implementation of a Biosphere Reserve network; however, we need to take fuller advantage of the ideas and information from different groups which will lead to a better understanding of the larger regions represented by the whole set of reserves.

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GLOSSARY

BIOSPHERE RESERVE - Representative landscape unit reserved through the UNESCO- Man and the Biosphere Program for purposes of conservation, monitoring, and/or research. May include completely natural as well as semi-natural ecosystems.

BIOSPHERE RESERVE CLUSTER - A group of adjacent, but usually geographically separate biosphere reserves of both experimental and conservation types organized to address the complex objectives of the biosphere reserve network. Proposed by the United States to satisfy UNESCO-MAB objectives calling for the study of both natural and man-disturbed landscapes.

BIOSPHERE RESERVE FRINGE - Area beyond peripheral buffer zone which connects and/or surrounds a biosphere reserve cluster, but normally including more diverse land uses and ecosystem complexes than the reserves. Made available for studies of ecosystem disturbance and recovery, and of social impact and interactions with biota.

BIOSPHERE RESERVE NETWORK - The global set of biosphere reserves or reserve clusters linked by international understanding of purposes, standards, and exchange of information and personnel.

CONSERVATION RESERVE - Landscape unit established to conserve the diversity and integrity of biotic communities of plants and animals within natural ecosystems, and to safeguard the genetic diversity of species.

Background monitoring and research on the effects of recreational use are frequently conducted in such reserves. Landscape manipulations are usually restricted or prohibited. Examples include National Parks, Wilderness Areas, and conservation-type Biosphere Reserves.

CODE AREA - Geographical subdivision of a biosphere reserve devoted almost wholly to conservation.

EXPERIMENTAL RESERVE - Landscape unit established to evaluate major anthropogenic effects (pollution, harvesting, land-use change) on local and regional ecosystem structure and function. Monitoring of ambient conditions is frequently carried out as well.

EXPERIMENTAL ECOSYSTEM RESERVE NETWORK - Set of experimental reserves in different biogeographic provinces of the United States which offer the opportunity for experimental, manipulative research to evaluate the impacts of current, planned, and as yet unforeseen activities of man.

PERIPHERAL BUFFER ZONE - Geographical subdivision of a biosphere reserve which surrounds and hence protects a core area, and where the effects of landscape manipulations on ecosystem structure and function can be assessed.

Research, Monitoring, Inventory, and Education at Great Smoky Mountains National Park

by

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GENERAL DESCRIPTION, PURPOSE AND USES OF THE PARK

Great Smoky Mountains National Park is a 208 370 hectare natural area whose resources the Federal Government set aside, in 1934, to be preserved for the benefit and enjoyment of this and future generations. In 1975 alone, the Park experienced eight and one-half million visits by individuals who came to enjoy viewing its massive, rugged mountains, the lush abundance and diversity of its plant life, and the varied animal life that thrives in its unspoiled wildlands. In several historic zones within the Park visitors may see and learn something about the homes, barns, mills, and churches which are preserved as reminders of the distinctive pioneer culture that once characterized the southern Appalachians.

The Park is within 2 days' easy driving distance of nearly two-thirds of the population of the United States. Most visitors come from the nearer Midwestern and Southern States, but it is also a focal point of national and international interest.

SPECIAL QUALITIES OF THE PARK

Although the Smokies rise more than a mile above the adjacent lowlands (Park elevations range from 240 to 2 040 meters), and its slopes are extremely steep, the visual impression given is of worn, massive ridges fading into blue distances. Lacking the jagged spectacle of the Rocky Mountain and Sierra Parks, the gentle beauty of the Park is augmented by its appeal as the largest terrestrial sanctuary in the Eastern United States — and by the extraordinary quality of its ecosystems. For most who come to the Park, the experience enjoyed centers on touring parts of the more than 300 kilometers of primary roads. Studies, however, indicate that a major aspect of the pleasure they derive from the Park comes from knowing that most of it is wilderness, unspoiled by roads, buildings, other developments, or the activities of mechanized equipment. In addition, more than 120,000 visitor nights of backcountry camping and at least 800,000 instances of day-hiking, annually, provide visitors with experiences not duplicable elsewhere — experiences the quality of which engenders, among many, an intense feeling of loyalty to the principles of wilderness preservation.

The specific natural qualities that make the Smokies especially valuable to those who perceive them — whether casual visitor, hiker, or scientist—include:

- Very high diversity of temperate flora (about 1,400 species of flowering herbaceous plants, 2,200 other plant species), with large numbers of species occurring in the same stands. One of its major forest types, the Cove Forest, has 25 to 30 tree species, with 6 to 12 dominant on any one site. A one-tenth hectare plot may support 40 to 50 species of herbs.

- Flora highly representative of the Eastern Forest Biotic Province, over continuous gradients in both disturbed and undisturbed ecosystems, and over a wide range of elevations and exposures. Those areas previously cut over have been recovering for varied periods of time, thus representing diverse successional stages.

- Ecosystems stability, as a result of protection from excessive human impacts and of the diversity of life forms composing the Park's ecosystems.

- Associated with such diversity of flora and site conditions, a highly diverse array of animal species, some of them spectacular and appealing to the public (e.g., black bear, white-tailed deer, wild turkey, and the rare mountain lion), and others of special scientific interest.

- Numerous watersheds in which thousands of hectares of roadless terrain feed streams whose purity is unexcelled by streams of comparable flow and accessibility anywhere in the United States. Some of these watersheds are unaffected even by trails. Approximately 500 billion gallons of surface water flow from the Park each year. (Annual rainfall in the Park ranges from 1 200 to 2 500 millimeters)

- Large expanses of virgin forest, totaling about 70,000 hectares (an imprecise figure, as some areas were logged so selectively—and long enough ago—that it is difficult to be sure how much was never logged). Dominant tree species include *Abies fraseri* (Fraser fir), *Acer rubrum* (red maple), *Acer saccharum* (sugar maple), *Aesculus octandra* (yellow buckeye), *Betula alleghaniensis* (*B. lutea*) yellow birch), *Carya* species (hickories), *Fagus grandifolia* (beech), *Picea rubens* (red spruce), *Halesia carolina* var. *monticola* (silverbell), *Liriodendron tulipifera* (tulip poplar), *Pinus* species (pines), *Quercus* species (oaks), *Tilia heterophylla* (basswood), *Tsuga canadensis* (hemlock).

- The largest block of virgin red spruce forest remaining on earth, and North America's southernmost limit of the range of that and many other northern species.

- Extensive areas sheltered from the effects of many of the air pollutants that affect most of the Eastern United States. (Sulphates and nitrates are coming in, however).

- Preservation in perpetuity (thus giving long-term research opportunities not assured elsewhere) of many plant and animal species which are uncommon, endemic, or exist outside of the Park only as fragmented populations. These are essentially free from major human interference, interruption by roads, and impairment by such things as housing areas or industrial developments. The value of the gene pools thus protected is beyond estimation.

- Ease of access, because of its proximity to major population centers—and, internally, by virtue of its extensive trail system (more than 1 200 kilometers maintained).

- A large accumulation of data, as a result of the unusual amount of scientific interest that has centered on the Smokies over the years.

FACTORS INFLUENCING ECOSYSTEMS INTEGRITY

Human enjoyment is a basic reason for the establishment of Great Smoky Mountains National Park; and the ways in which people enjoy the Park affect, to various degrees, the integrity of its resources. Accepted uses include touring Park roads by motor vehicles; camping in the 1,100 individual sites provided in the nine campgrounds accessible by automobile; day-hiking; backpacking for stays of 1 or more nights in the backcountry campsites (118 of them, of which 20 have a lean-to shelter); trout fishing, wading, swimming, and floating (mostly on inner tubes) in or on the creeks and rivers; horseback trips, by the hour or for as much as several days and nights in the roadless areas; participating in various interpretive activities (self-guiding or with the guidance of staff interpreters); and such associated pastimes as photography, meditation, wildlife observation, and other forms of informal nature study.

Most of these uses bring direct physical impact on resources—as do most research activities in the Park. I believe we must ultimately face the fact that impairment of pure natural conditions begins with the first footstep by a person wearing modern footgear, or incursion by an exotic species, and ranges to the total obliteration of areas by paving. Where we draw the line depends, finally, on subjective judgment. In making decisions that may have significant ecological, social, or economic impacts, we are required by law to make public our analysis of such impacts, and to take into account the views of all interested parties, governmental and private, as expressed through written comments, public hearings, or both. No decision is likely to satisfy everyone; and in any case, the Park is not, and cannot be totally free of the influences of modern technological humankind. The extreme ruggedness of its terrain and density of its vegetation, though, are such that most visitor use is concentrated along its roads and maintained trails—leaving virtually intact a large number of areas within the Park, each of which is larger than many entire Reserves.

The Park is surrounded by a population that includes many whose forbearers harvested the plant, animal, and mineral wealth of the

area with little or no outside control. Some of these (and other) people continue such activities, illegally, in the Park. Bear, deer, grouse, and other animals are killed; and various plants are removed (most notably, ginseng and ramps). Some thoughtless or uninformed visitors collect flowers and shrubs, carry away attractive rocks, or kill animals which they consider undesirable (e.g., poisonous snakes). A protection staff varying, seasonally, from 35 to 55, carries the primary responsibility for controlling such activities.

Its value as a place for non-disruptive scientific research is high among the reasons for Great Smoky Mountains National Park's existence as a Park. Substantial effort is now being made to facilitate such research whether aimed at the solution of immediate management problems or simply the increase of human knowledge of the environment and its components.

RELATIONSHIPS BETWEEN MANAGEMENT AND RESEARCH

Much of the management effort in the Great Smokies is now directed at keeping human impacts at as low a level as is possible, given the kinds and amounts of uses that are expected and accepted. For that reason, research efforts funded by the National Park Service are directed primarily at monitoring such impacts, and at developing methods for reducing, eliminating, or compensating for them. Such research is done by National Park Service employees, or under contracts with universities or private firms.

A great deal of other research is done in the Park, though, by scientists whose interests don't relate so clearly to our management concerns, but who are supported by funds from other sources. Such sources include other Federal agencies (National Science Foundation, RAND, ERDA, EPA), private foundations, privately endowed conservation organizations, and even interested individuals financing their own research or that of others. Much of the information gathered in such projects eventually will become very valuable to management of the Park's resources—or is immediately valuable in making management decisions affecting other aspects of the human environment.

The Park has already attracted much scientific interest (at least 1,000 scientific papers have been published, relating to the Park), but the role of Service personnel in conducting or supporting research has varied from time to time. At Great Smokies, as throughout the National Park System, awareness of research values and needs is at a new high, and is apparently ascending.

We are now making concerted efforts to conduct and coordinate research under the guidance of highly qualified professional scientists. The work is being conducted with the newly established Uplands Field Research Laboratory in the Park as its base. Emphasis is on the solution of obvious management problems. Included among these are such things as work on the dynamics of the Park's population of exotic wild boar (which arrived, uninvited, more than 30

years ago), and the means of bringing it under control; the influence of certain exotic plants; the influence of the balsam woolly aphid; the impacts of hiking, horseback riding, and camping on Park ecosystems; methods by which certain communities (grassy balds) may be held at a seral stage deemed desirable because of their unique qualities; and the dynamics of the Park's native brook trout population as it relates to human activities; and the effects of two exotic species of trout.

But we have a long way to go. Unfortunately, we are faced with the necessity of answering these management problems without benefit of an adequate systematized base of inventory work. Inventorying must therefore be accomplished while we are coping with the management problems. Such inventorying includes work as basic as the development of a reasonably detailed vegetation map of the Park; stream classification; rare and endangered species survey; soils mapping; and fuel-loading mapping. With assistance from other agencies (for example, ERDA, the Weather Service), we must monitor as thoroughly as possible the full spectrum of factors influencing the environment, including weather, air and water pollution, and animal population trends. By such means, it should be possible for us to recognize problems before they become serious, or preferably to foresee them in time to take the steps necessary for avoiding them.

Dr. Stanley Cain, whose ecological studies are among the most significant done in the Park, developed information from which the following elements—representing probably the minimum considerations that should be included in the Park's ecological research programs—were derived:

1. Continuing program of floristics and faunistics, with suitable museum and herbarium vouchers for species present in the Park.

2. Basic description of the composition and structure of the Park's vegetation and associated animal life—(a) existing communities (major cover types and special habitats); (b) how component species are organized; (c) indicator species for given community or ecologic situations; (d) successional patterns in various communities.

3. Biogeographic features—endemics, range extremes.

4. Rare and endangered species.

5. Predator-prey relationships, food chains.

6. The nature of territories, ranges, carrying capacities, population cycles.

7. Phenological data.

8. Quantitative study of the trophic levels of biotic communities, including periodic censuses of the dominant vertebrates and invertebrates and estimates of the biomasses, fecundity and rate of turnover of the most important populations.

9. Analysis of climatic trends.

10. Detailed soil survey.

11. Conditions in undisturbed environment as it may have existed before the arrival of European man—(a) variations of current ecological conditions from the original; (b) factors that caused these deviations; (c) the practicability of recreating original ecological conditions where impairment has occurred.

12. The direct effects of visitors on important natural features.

Research projects may be funded by the National Park Service, other Federal agencies, State agencies, universities, or private sources. Any one of them may involve personnel and funds from more than one of those sources.

Since the Park's establishment, hundreds of scientists have undertaken a broad range of research projects. The greatest emphasis has been on vegetational research, but many of the animal groups, particularly salamanders, have also been investigated and there have been a number of geological studies.

More than 80 separate projects were in progress from 1972 through 1975, and during that time approximately 20 were completed. Most of the research is the work of university faculty and students, but in some cases projects are undertaken by National Park Service employees.

Past studies include significant vegetational research by Cain (1930a, 1930b, 1931, 1935, 1936, 1943, 1945), Shanks (1954a, 1954b, 1956) and Whittaker (1956, 1961, 1962, 1963, 1966); the early vegetational mapping that was done by Miller (1941); studies of grassy bald succession by Gersmehl (1970), Lindsay (1976), Mark (1958, 1959) and Wells (1936a, 1936b, 1938); a plant reference list compiled by Hoffman (1964, 1966), and the investigations of fungi by Hesler (1960, 1976) and bryophytes by Sharp (1936, 1939; Cain and Sharp, 1938).

As for important studies related to the Park's fauna, Barr (1962, 1969a, 1969b) has worked on the carabid beetle fauna; Whittaker (1952) studied the summer foliage insect communities; and King (1937, 1939a, 1939b, 1942, 1944) reported on trout management studies, and surveyed the herpetology of the Park. Hairston (1949, 1950, 1951), Highton (1962, 1971; Highton and Henry, 1972), Huheey (1959, 1960, 1961, 1966a, 1966b; Huheey and Brandon, 1973), Tilley (1968, 1973, 1974) have done a considerable amount of research on the ecology, geographic variation, and distribution of plethodontid salamanders. Bird life has been investigated by Ganier (1926, 1931, 1962; Ganier and Clebsch, 1938), Stupka (1963) and Tanner (1952, 1955, 1957); the ecology of the European wild boar has been investigated by Bratton (1974, 1975a, 1975b) and considerable information on the ecology of the black bear in the Park has been contributed by Pelton and his students (Pelton 1970, 1974, 1976; Pelton and Burghardt, 1976; Beeman 1971, 1975; Eubanks, 1976; LaFollette, 1974; Marcum, 1974).

Much of what is known about the Park's geology is summarized by King, Neuman and Hadley (1968).

Proper management of the Great Smoky Mountains National Park—management to assure continued *enjoyment* of its distinctive qualities, and the full measure of knowledge that may be derived from study of its undisturbed natural resources—is *dependent* on effective research, monitoring, and inventory. This work can be done with maximum efficiency only if done with full knowledge of work being done in similar or related areas around the world. The MAB program offers our greatest hope for sharing with you and other nations the benefits of all such work.

EDUCATION IN THE PARK

A major aspect of Park operations is its interpretive program, through which public perception, understanding, and appreciation of its features and values is developed. This program, conducted by a staff ranging in number, seasonally, from 8 to 72, includes the preparation and presentation of publications, exhibits, slides, films, audio devices, guided walks, auto caravans, and hikes, and talks. The planning and production of many of our interpretive devices is done with the assistance of the National Park Service's Harpers Ferry (West Virginia) Center, by use of the Center's specialized personnel or by contracting with private firms. The Park is thus a part of a national network of educational resources focusing on outstanding natural and cultural values.

Several thousand students from elementary and secondary schools throughout the Southeastern States are given week-long training sessions based on the Park's natural environment, at the Tremont Environmental Education Center. This facility, built by the U.S. Government, is managed under a contract with Maryville College. It operates at capacity throughout the school year. In addition to its programs for young students, it provides training for teachers and prospective teachers in the concepts and techniques of environmental education—thus encouraging both improved effectiveness in student use of the Center, and continuing influence beyond the immediate experience at the Center.

College students are deeply involved in research in the Park. Interns at the undergraduate level assist in the subprofessional aspects of research work, thus preparing themselves for work at the professional level. Much of the research itself is done by graduate students, guided by qualified academicians and with broad coordinative direction from the Service's professional personnel. Our knowledge of Park resources is thus increased by a process that is integral to the development of scientists competent at the highest professional level. College students also receive instruction from Park personnel during group field trip visits.

The exceptional diversity of the Park's life forms and terrain, the extent of its ecological integrity, and the presence of highly qualified personnel, make it particularly valuable as a place for the training of National Park Service (and other government) personnel. Although such training has been largely on a one-by-one basis (special assignments, temporary details), plans are now being considered for

the use of the Park in the training of groups of personnel engaged in 1- or 2-week sessions dealing with resource management and other aspects of natural area operations.

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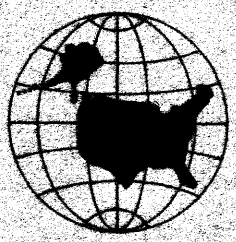
Monitoring on Biosphere Reserves for Regional Background Levels of Pollutants

by



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INTRODUCTION

Man's impact on the environment has had a far-reaching and at times a catastrophic effect. Long gone are the days when the pollution emitted by man impacted only his immediate surroundings. Today, pollution problems are truly global in nature and transcend any or all national or political boundaries. This problem is becoming even more critical now that much of the world is facing an energy shortage. Many nations are being forced to turn from oil to potentially more environmentally harmful fuels such as coal. In addition, even supposedly "clean" alternate energy such as geothermal resources have the potential for environmental contamination from a number of trace elements and gases. The Study of Critical Environmental Problems Report (Massachusetts Institute of Technology 1970) stated: "Over the past few years, the concept of the earth as a 'spaceship' has provided many people with an awareness of the finite resources and the complex natural relationships on which man depends for his survival. These realizations have been accompanied by concerns about the impacts that man's activities are having on the global environment. Some concerned individuals, including well-known scientists, have warned of both imminent and potential global environmental catastrophes."

The task of estimating the extent and the magnitude of man's impact on the global environment is challenging. Morgan et al. (1975) said, "Man's technological advances and increasing population have caused a significant impact on our environment. We are now faced with the

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arduous task of describing on a global basis those factors that impinge on environmental quality. This information is needed by both the researcher and the official who must not only assess environmental quality, but also control emissions into all aspects of the environment."

There has been a tremendous amount of discussion, meeting, and thought given to a Global Environmental Monitoring System (GEMS). A variety of organizations and committees, including but not limited to the U.S. International Task Force of the Global Network for Environmental Monitoring, the Global Monitoring Task Force of SCOPE, the Man and Biosphere Expert Panel on Pollution, the SCEP, Task Force II--Committee on International Environmental Affairs, and the SCOPE Commission on Environmental Monitoring and Assessment have called for the formation of such a global monitoring network.

The United Nations' Conference on Human Environment (Man and Biosphere 1974) held in Stockholm in June 1972, recommended the establishment of EARTHWATCH, which has a four-pronged program including monitoring, research, evaluation, and information exchange. The ultimate objective was the establishment of GEMS. The seven program objectives of GEMS are:

1. *An Expanded Human Health Warning System*

   Selected health effect indicators and associated environmental parameters will be monitored so as to provide for early detection of potentially harmful conditions. The disease statistics now compiled on a global scale from ongoing national and international health activities would be augmented to provide for improved warnings.

2. *An Assessment of Global Atmospheric Pollution and Its Impact on Climate*

   The network of atmospheric baseline monitoring stations now being developed would be expanded to provide for a more comprehensive assessment of pollutant and climate trends. Measurement of additional critical pollutants would be made as part of a global monitoring network.

3. *An Assessment of the Extent and Distribution of Contaminants in Biological Systems, Particularly Food Chains*

   Potentially harmful contaminants in food would be monitored to provide early warnings for protecting human health. Existing national and international programs for monitoring harmful pollutants in fish and other food prominent in international trade provide a base for implementation.

4. *An Improved International Disaster Warning System*

   Countries in regions of high natural disaster potential will be assisted by teams of technical specialists to establish plans for regional monitoring systems and centers, as well as predisaster preparedness. Atmospheric, oceanic, volcanic, and earthquake hazard warnings will be addressed.

5. *An Assessment of the State of Ocean Pollution and Its Impact on Marine Ecosystems*

   Selected pollutants will be monitored at a small number of remote locations in the world's oceans on a continuing basis to assess long-term trends. Major sources of ocean pollution which contribute to regional contamination, such as river outflows, will be monitored to complement baseline observations and permit assessment of impacts on regionally important ecosystems. The interaction of the ocean, land, and atmosphere in pollutant transport will be assessed.

6. *An Assessment of the Response of Terrestrial Ecosystems to Environmental Pressures*

   The direct and indirect impact of environmental pressures, anthropogenic and natural, on terrestrial ecosystems will be monitored. Ecosystem monitoring programs presently underway will be expanded to focus on ecological areas presently not receiving adequate attention.

7. *An Assessment of Critical Problems Arising from Agricultural and Land-Use Practices*

   Certain aspects of agricultural and land-use practices will be monitored for their environmental effects on natural systems.

As part of this global and environmental monitoring system, it has been recommended that Biosphere Reserves be established. For example, the U.N. Conference on the Environment (1972) recommended that biological reserves be established within the framework of the report "Man's Impact on the Global Environment" (Massachusetts Institute of Technology 1970) which recommended similar type entities, calling them ecological baseline stations in remote areas on Biosphere Reserves.

Biosphere Reserves may be defined as undisturbed and protected natural background areas of the earth where life naturally occurs and interaction takes place among the living organisms and with the non-living environment.

The needs for these Biosphere Reserves are obvious.

1. They provide a permanent record of the "natural" state of the environment.

2. They would ensure undisturbed areas from which background data on pollutant levels could be obtained.

3. They can potentially serve as early warning sites for more dangerous buildups in higher impact areas.

4. They serve as repositories for natural sources of genetic pools of animal and plant species.

ENVIRONMENTAL MONITORING

Environmental monitoring is defined as the systematic collection of physical, chemical, biological, and related data pertaining to environmental quality, pollution sources, and other factors that influence or are influenced by environmental quality. Environmental quality data are vital in determining the exposure of critical populations at risk and include measurement of pollutant concentrations in air, water, soil, and food at locations where exposure may occur. The complexity of environmental or exposure monitoring can be appreciated if one considers that acute or chronic effects may result from either a single short-term peak exposure, repeated short-term high-level exposures, or a low-level long-term exposure. Further, one must consider the possibility that a single pollutant may cause or contribute to the aggravation of several different environmental effects. Frequently, the environmental contribution in such cases can only be recognized because of an increasing level of adverse effects, such as elevated rates of cancer in relatively isolated areas. In many instances, measurements of pollutant levels in areas designated as clean, i.e., Biosphere Reserves, can give man a clue or a warning of potential environmental danger, particularly from adverse synergistic effects that may be masked in areas of high impact. Thus, there is a requirement for a better quantitative measurement of exposure of Biosphere Reserves to the adverse effects of background levels of biological, chemical, and physical agents.

The relationship between elevated short-term exposures or acute exposures and adverse environmental effects is more easily recognized than is the case for long-term low-level exposures. In order to support research on long-term environmental changes in Biosphere Reserves, an integrated monitoring system is necessary to furnish an accurate estimate of exposure. While measuring the exposure of a receptor to chemical or physical agents, data from the integrated monitoring system would be used to quantitate the contribution of each pathway and the chemical or physical forms of the pollutants present. Exposure assessment must also consider such variables as frequency, duration, and intensity of exposure and necessary supporting data such as temperature, humidity, etc.

The monitoring of air, water, and soil, along with tissues and biological fluids collected from plants, wildlife, and domestic animals, can indicate levels, patterns, and trends of environmental pollutants or their metabolites. The health, growth, and number of plants or their accumulation of pollutants may be a useful indicator or early warning of environmental contamination that may adversely affect human health. For example, some lichens are extremely sensitive to sulfur dioxide. In addition, incidences of pollution may be detected by unusual changes or mortality in animal populations in Biosphere Reserves; for example, those documented following exposure to DDT, mercury, lead, fluorides, and aflatoxins. Exposure or receptor monitoring is also required for developing and verifying predictive models linking source emissions to ambient levels.

Exposure monitoring may be done at fixed or movable ground stations or from aircraft. The sensors used may be for contact sensing point measurements or for remote sensing long-path measurements.

All monitoring systems must consider the following aspects in the design stage:

1. Station siting.
2. Sampling.
3. Sample handling.
4. Sample analysis.
5. Data storage and retrieval.
6. Representativeness of data and reporting format.

In addition, the frequency of sampling and the sampling time are important variables to consider as they relate to the monitoring objectives.

CRITERIA FOR ESTABLISHING SAMPLING SITES IN BIOSPHERE RESERVES

The criteria for sampling sites in Biosphere Reserves have been established, to a large extent, by existing programs. Criteria for establishing Biosphere Reserves sites have been proposed in a variety of reports. These include Morgan et al. (1975), the Report of the Ad Hoc Task Force on GNEM (1970), the SCOPE Report 3 (Munn 1973), and MAB Report 22 (Man and Biosphere 1974). From these reports one can readily draw a list of criteria as follows:

1. The stations should be located in an area where no significant changes and use practices are anticipated for at least 50 years within 100 kilometers in all directions from the stations.

2. They should not be downwind or downstream from major sources of pollutants and should be located away from major highways and air routes.

3. The sites should be at least 100 kilometers from urban centers over land and at least 150 kilometers away from urban centers if maintained along major rivers. The site should experience only infrequent effects from local natural phenomena such as volcanic activity, forest fires, and dust or sand storms.

4. The observing staff should be small in order to minimize the contamination of local environment by their presence in their living quarters.

5. All requirements for eating and cooking, etc., should be met by electrical power generators away from the site.

6. Access to the station is limited to those necessary to the operation of the station.

7. The reserved land areas should be protected from nonessential people and vehicles, but should not be fenced to the extent that natural movement of animals is significantly curtailed.

The question now becomes the number and precise location of the sites. An actual location within a biome will probably be determined by the criteria for establishing it. The number of locations which will meet the rigorous requirements for siting is probably limited. In addition, resources to fund and study the sites are also limited. Hence, the selection criteria exert a self-limiting influence on the problem. Here we must pause and confine this discussion to terrestrial sites to obtain some perspective of operational fund requirements. Morgan et al. (1975) estimate that the cost of operating an on-site continuous monitoring station could range between $100,000 to $375,000 a year in U.S. dollars. Obviously, cost is a major consideration in establishing such a monitoring effort.

A list of pollutants is given in MAB Report 20 (Man and Biosphere 1974b). Also, pollutants are listed in the GNEM Report (Ad Hoc Task Force on GNEM 1970) and the SCOPE Report (Munn 1973). From these, we can draw a tentative list for monitoring the Biosphere Reserve (table 1).

Table 1--Suggested list of pollutants considered to be monitored at Biosphere Reserve sites[1/]

Pollutant	Environmental component				
	Air	Surface water	Ground water	Soil	Biota
Sulfur dioxide	X	--	--	--	--
Suspended particulates	X	--	--	--	--
Turbidity	X	X	--	--	--
Chlorides	--	X	X	X	--
Biochemical oxygen demand	--	X	--	--	--
Dissolved oxygen	--	X	--	--	--
Coliform bacteria	--	X	X	--	--
Phosphorus (PO_4)	--	X	X	X	--
Organic nitrogen	--	X	X	X	--
Ozone	X	--	--	--	--
DDT and other	X	X	X	X	X
Chlorinated hydrocarbons	--	--	--	--	--
Cadmium	X	X	X	X	X
Mercury	X	X	X	X	X
Lead	X	X	X	X	X
Arsenic	X	X	X	X	X
Nitrogen dioxide	X	--	--	--	--
Carbon monoxide	X	--	--	--	--
Fluorocarbons	X	--	--	--	--
Reactive hydrocarbons	X	--	--	--	--

[1/] Other items for measurement, although not necessarily pollutants, are solar radiation, meteorology conditions, rainfall, soil characteristics, hydrology, and biological characteristics.

For the most part, adequate baseline data can be obtained for approximately $100,000 per station per year. For any monitoring station a subset of pollutants should be selected from table 1 to meet the objectives of the monitoring program. Also, continuous monitoring is not required for all pollutants. Statistically valid data may be obtained by selecting an appropriate intermittent sampling scheme and by the use of composite samples when possible.

The priority for pollutants at a given Biosphere Reserve should be selected based on an agreed set of criteria. All of the criteria noted below should be taken into consideration when establishing priorities:

1. Severity of suspected or known adverse effects on the biological populations of the Biosphere Reserve.

2. Persistence of the pollutant in the environment, resistance to environmental degradation, and accumulation in man or the food chain.

3. Conversion to more toxic substances.

4. Ubiquity and abundance in the environment.

5. Size and type of population exposed, frequency and magnitude of exposure.

6. Physical effects on the Biosphere Reserves such as soil permeability, etc.

7. Availability of adequate methodology for sampling and analysis.

QUALITY ASSURANCE COMPARABILITY OF MEASUREMENTS AND DATA QUALITY CONTROL

A basic requirement of any national or international monitoring program is that the data generated by one program or monitoring system be fully comparable to similar data produced elsewhere or at another time. In other words, the degree of accuracy and precision of all data must be known. This necessitates an active quality assurance program. Quality assurance can be defined as maintaining a certain prescribed standard of performance or output throughout the monitoring operations from beginning to end.

Various laboratories employ different methods for analyzing environmental samples. The analytical techniques, instrumentation, calibration procedures, analytical technicians, and chemical reagents used, usually differ both from laboratory to laboratory and over a period of time for a given laboratory. These interlaboratory and intralaboratory differences often lead to important systematic discrepancies between measurements of pollutant concentrations in the same matrix material. An effort should be made to overcome these difficulties by the use of reference methods. Some national and international groups have already selected such methods for several environmental agents and agreed upon approaches for the evaluation of equivalency.

As related to the monitoring of Biosphere Reserves, quality assurance applies to many areas such as personnel, equipment, data, and procedures. It applies not only to the component aspects of a monitoring system but also to their interrelationships and functions as a whole system. Therefore, quality assurance must be considered in the design, implementation of, and assurance of adherence to guidelines in the following areas:

1. Site selection.
2. Site verification.
3. Type and number of stations.
4. Selection of instruments and methods.
5. Sampling procedures.
6. Sampling frequency.
7. Instrument maintenance and calibration.
8. Historical operational records.

Other related areas which must also be considered with the above list are training and evaluation programs, calibration standards and their proper use, data handling, verification, storage, and coordination, and communications.

A total quality assurance program which implements the above principles would consist of four major elements.

1. Development and issuance of procedures.
2. Intralaboratory quality control program.
3. Interlaboratory quality control program.
4. Monitoring program evaluation.

All of these elements are equally essential and must be developed and carried out simultaneously.

THE MONITORING NETWORK SYSTEMS

Integrated monitoring systems should be established in a variety of Biosphere Reserves representing the critical natural biomes. The main elements for such systems are:

1. Design of suitable monitoring systems.
2. Instrumentation and methodology standardization and quality control.
3. Field sampling and measurements of environmental quality, emissions, and effluents.
4. Laboratory analysis and evaluation of field samples.
5. Information synthesis including operation of technical information systems, data analysis, and preparation of reports.

As part of the integrated monitoring approach to the Biosphere Reserves, it is proposed that the source-to-receptor concept be employed at each site. In this particular case, the immediate source is going to be general environmental transport. In a remote site, it is difficult to envision any other source for pollutants unless the site is downwind or downstream from a nearby major pollutant source. This very fact, however, may preclude the selection of that location as a Biosphere Reserve site.

For the purpose of the following scenario, the integrated design will be approached with the idea that the primary source of the pollutant is general global atmospheric fallout. The critical receptor for the pollutants is the Biosphere Reserve site itself. As the knowledge of that site increases, one's ability to conduct biological monitoring surveys increases, and the critical receptors can be defined to more specific components within the biosphere site itself. We hope much of the research that is going to be conducted as part of the Man and Biosphere program will allow for identification of components within each of the Biosphere Reserves which could be considered critical receptors.

The question now becomes what environmental components should be monitored. Since one of the critical philosophical underpinnings of the Biosphere Reserve concept is that human activity on these reserves must be minimal, intensive ecological studies, research projects, sampling programs, and so forth are precluded. Consequently, environmental monitoring activities on these sites must be conducted in as nondestructive a manner as possible.

The major items that should be monitored are shown in table 1. Since the atmosphere is a major transport route, it obviously must be monitored extensively. Any surface water within the Biosphere Reserve obviously must also be sampled for the appropriate pollutants. Ground water must be sampled, although the problem with sampling ground water is that usually the aquifer is so much larger than the proposed site of the Biosphere Reserve itself. Soil is a component that should be sampled for a variety of pollutants, particularly those from airborne sources.

The question of biological sampling in a Biosphere Reserve must be carefully considered. Although a great deal of information can be obtained from a biological sampling program, the living part of the reserve must be sampled very sparingly so as not to alter the normal balance of plants and animals. In some cases, the selective sampling of plants and animals can be quite effective in determining the concentration and trends of toxic pollutants in plants and animals. Table 2 is an example of average pollutant concentrations in selected animals and plants collected in background areas.

While the network design is considered, it is necessary to discuss some of the requirements of sampling and what differences in the year-to-year sampling are important for networks to detect. As an example, take the global pollutant, mercury. Research conducted by the U.S. Environmental Protection Agency (EPA) indicates that the global atmosphere is probably the ultimate sink of anthropogenic sources of volatilized mercury. This is likely to become

Table 2--Accumulation of selected heavy metals in biological organisms

Biological organism	Heavy metal			
	As	Cd	Hg	Pb
	(Concentration in ppm)			
Mollusks	--	30	30	4
Bird feathers	0.5	0.01	40	11
Marine plants	30	0.4	0.03	8
Marine fish	11	5	102	10
Crustacea	100	6	2	--
Freshwater fish	40	20	17	--

even more important with the increasing reliance on coal as a major source of energy.

Figure 1 is a diagram of results from a recent research program undertaken by EPA (Rogers 1976). Here, agricultural soils were

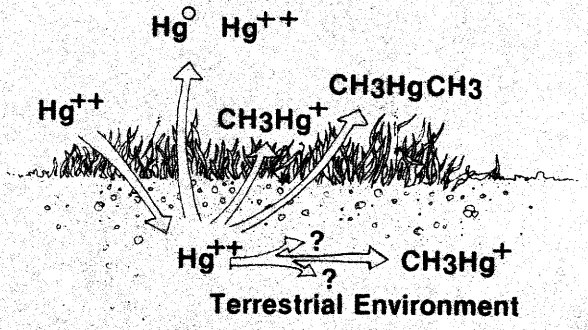

Figure 1.—Fate of mercury applied to agricultural soils. Evolution of methyl and dimethyl mercury from soils takes place within hours after ionic mercury is applied (Rogers 1976).

amended with ionic mercury. They were then extracted and analyzed for the presence of methylmercury. As figure 1 shows, methylmercury compounds are rapidly evolved from the soil surface back into the atmosphere. Similar research on mercury in plants (Gay 1976) has indicated that the plants themselves are capable of methylating mercury. Very recent research has tentatively indicated that dimethylmercury has been given off by plants grown in hydroponic solutions containing ionic mercury. In addition to this, a field monitoring program around known mercury point sources has been conducted (Crockett and Kinnison 1977). Soil and plants have indicated minimal buildups of mercury in areas where mercury was expected to be building up. The conclusions are tentative at this time, but they seem to indicate that one of two things is happening: (1) Methylmercury and other forms of mercury released to the atmosphere are being taken up by mammalian systems living in the area, or (2) mercury is being redispersed into the atmosphere.

Another important consideration is the number of samples to be collected to achieve the desired level of precision. Figure 2 shows the curve for mercury residues in soil which illustrates the problem that we will have to face when sampling Biosphere Reserves. For example, notice that up to about a 10-percent sampling error, a relatively small increase in samples results in a rather large increase in precision. Beyond the 10-percent sampling error, i.e., approaching a 5-percent sampling error, the numbers of samples required to achieve the additional precision are rapidly becoming prohibitive. Note that at 50 samples of soil, there exists a sampling error of approximately 13 percent. At 100 samples, the sampling error has only been decreased to 9 percent and at 200 samples, it has only been decreased to 7 percent.

Although one expects different variance estimates of mercury residues at various Biosphere Reserves, one can still expect that a reasonable ball-park estimate for a 10-percent level of precision is going to require at least 50 different soil samples.

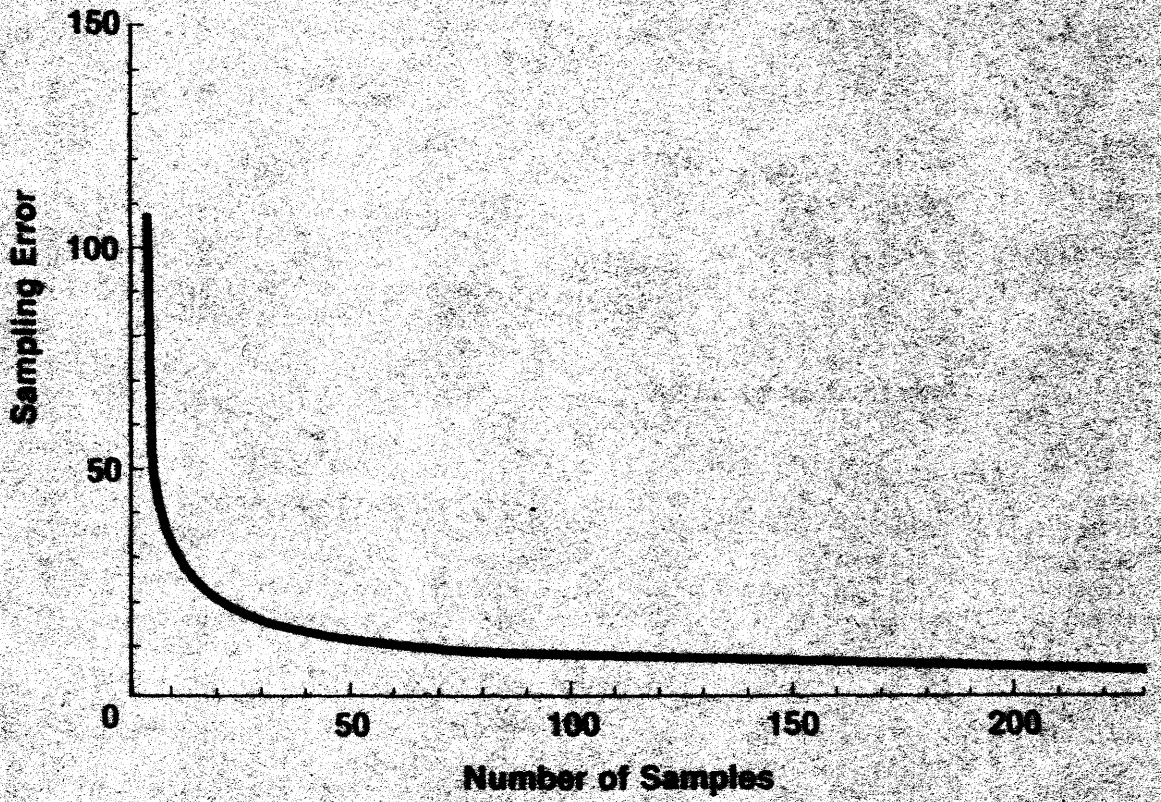

Figure 2.—Curve showing relationship between sampling error and number of samples for mercury residues in soil.

Figure 3 shows similar data for *Gutierrezia*, a common desert plant, which shows very similar results to soil. One needs at least 50 samples of the plant to achieve better than a sampling error of approximately 13 percent.

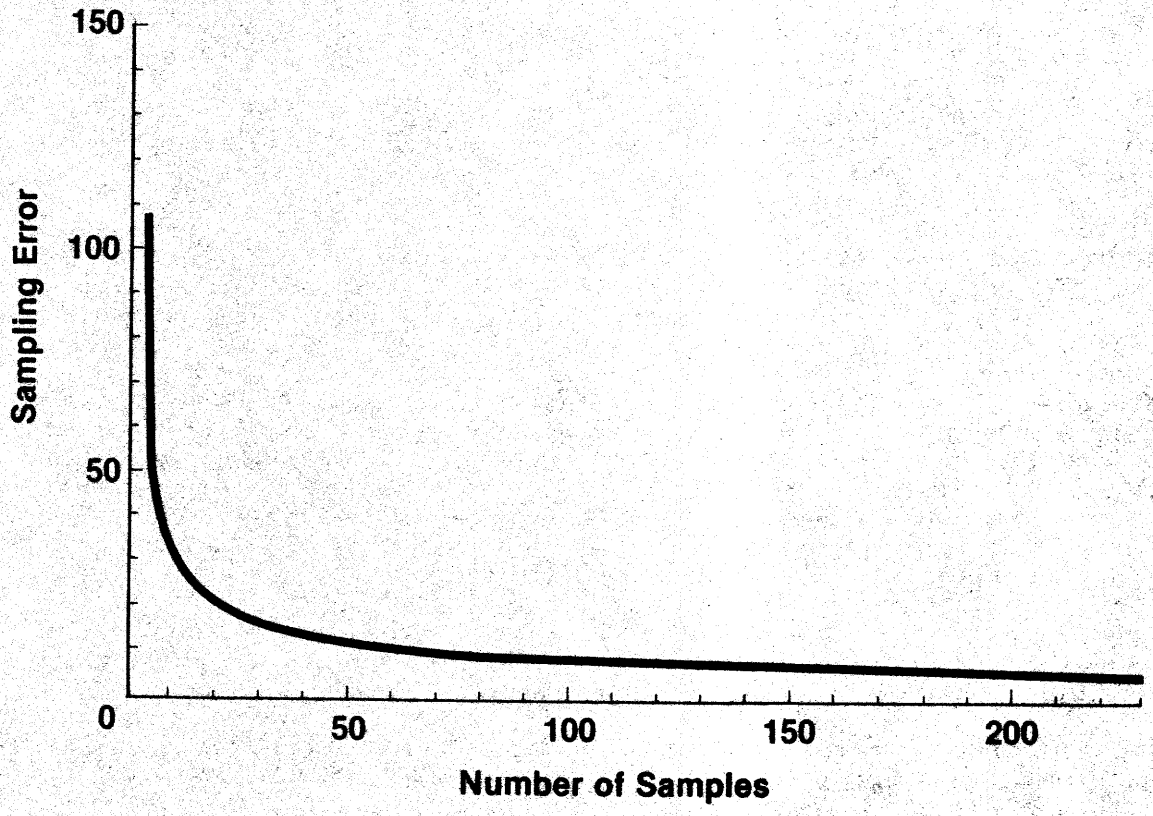

Figure 3.—Curve showing relationship between sampling error and number of samples for residues of mercury in *Gutierrezia* spp.

The question then becomes somewhat simplified. For example, what differences in mercury concentration are you trying to detect in the annual or semiannual samplings? Can one reasonably expect the background levels of mercury to change by 10 percent each year? Are they ever likely to change by 5 percent a year? Figure 3 shows that after a 5-percent sampling error, the slope of the curve becomes practically zero. Similar curves can be generated for other pollutants.

Another thing that must be considered when establishing a Biosphere Reserve is the inventory of existing biological communities. The inventory must be accomplished, of course, in a way which is not damaging to the existing communities. This problem is greater with animal communities than with plant communities.

There are other techniques for assessing changes in ecological systems, including species diversity indices, indices of association, and so forth. All of these depend on some form of sampling, some form of counting, and are, therefore, going to have to deal with inherent variability. Jenkins (1971) makes a compelling case for using biological monitors, indicators, and sentinels. Although there is some indication at this time that they have limited usefulness, there is agreement with the statements put forward in the GNEM (Ad Hoc Task Force on GNEM 1970): "We have sought diligently for universal indicators of the biological state of the globe, and have essentially failed. We can, and have, identified many candidates for the particular monitoring purposes in particular locales, but the diversity of life forms, the multitude of habitats for various combinations of species, and the intricately complex interactions among species--to say nothing of their interactions with widely-ranging climates and surroundings--all these features appear to preclude a few simple indicators of "how goes it" among the earth's living inhabitants. This state of affairs also emphasizes the presence--at least in the natural biological--of a significant stochastic component in such ecological measures as species diversity. This essential uncertainty in the natural ecological condition of any particular habitat or biome is the background noise against which observed ecological changes must be judged. Except for extreme changes which completely overrule natural selections and survivability, we are only beginning to perceive the combinations and permutations of life forms which may obtain under otherwise similar environmental conditions."

SPECIAL CONSIDERATIONS

In addition to the collection and analysis of environmental samples, there are presently a number of new instrumentation techniques which have a great potential for nondestructive measurements of the state of the environment as influenced by pollutants. Some of these are as follows:

1. Some of the new techniques of remote sensing from satellites offer an excellent method for ecological research as related to pollutant problems especially as a complement to ground-based networks. With an increase in resolution, the earth resources satellites could provide a continuous overview of the Biosphere Reserves.

2. It is now possible to measure a number of physical and chemical parameters by airborne platforms. Presently, both fixed and rotary wing aircraft routinely measure pollutants such as CO, O_3, CO_2, SO_2, NO, NO_2, suspended particulate matter, and hydrocarbons as well as temperature, humidity, and particle count and distribution.

3. The feasibility of employing remote sensing techniques using high-altitude aircraft are being tested in the following areas:

   a. Detecting stress in vegetation through the use of laser fluorosensing techniques.

b. Measuring water quality, particularly dissolved organics using laser-induced fluorescence emissions.

c. Measuring O_3, SO_2, and CO through the use of active laser-lidar systems.

d. Measuring sediment in water, chlorophyll and biological distribution using multispectral techniques.

e. Measuring energy-related pollutants and effects using overhead remote sensing and photographic techniques.

f. Identification and concentration of selected hazardous substances in water bodies using multispectral scanning techniques.

Such systems would permit to a large extent the rapid monitoring of Biosphere Reserves on a noninterference basis.

4. There are a number of new multielement or multicompound analytical techniques which are accurate, reproducible, automated, and becoming available worldwide. Some of these include energy dispersive x-ray spectrometry, isotope Zeeman atomic absorption, spectrophotometry, plasma emission spectrometry, and gas chromatograph mass spectrometry.

5. Studies are underway to develop and evaluate existing biological indices as environmental monitoring tools. There are probably a number of indices available which must be tested for adequacy before they can be used in an operational monitoring program.

6. Another area which should be considered as a possible monitoring technique is productivity measurements. Traditional productivity measurements have involved the clipping and removal of vegetation on plots. This technique would be disadvantageous for Biosphere Reserves because of its destructive nature. Therefore, one should pursue the possibilities of direct field measurements of various physiological parameters that can be used as monitoring tools to estimate productivity on a site. They also allow the use of relatively small biological samples and thereby minimize impact to local biota. This raises interesting sampling problems which must be dealt with concerning representative samples. The smaller the sample collected, the less the chances are that it is representative of the population from which it was taken.

Finally, it is necessary to establish a sample bank. Particulate, soil, plant, and animal samples should be collected in sufficient quantity to permit the preservation of at least half of the sample. In many cases, pollutant problems exist which are not presently recognized, or for which proper methods and instrumentation are not perfected. In addition, a portion of many samples can be used to intercalibrate laboratories.

Much work must be done to optimize methods for preserving and archiving environmental samples. For some samples, simple dehydration is adequate, whereas for other samples which may be used for organic analysis, quick freezing, followed by sealing in an inert atmosphere, may be necessary.

In conclusion, an intensive study of the Biosphere Reserve is highly desirable, if not mandatory. Although there are many factors to be considered, a meaningful monitoring program can and should be initiated without delay.

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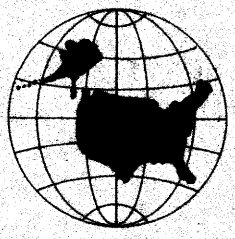
Some Basic Principles Concerning Biological Response to Environmental Change



by

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The ability to respond to environmental change is a basic characteristic of all known living systems. Although the types of environmental changes involved and the nature of the responses elicited can vary greatly with respect to time, space and other variables, there are some basic principles which can be applied to facilitate our understanding of the relationships between these processes at any or all levels of biological organization. An understanding of such principles is basic to the design of monitoring and/or research programs for Biosphere Reserve areas. Moreover, a basic understanding of the principles of biological response to environmental change will aid in critically assessing and eventually predicting the impacts of man's technology on ecological systems.

Our discussion of these matters is organized into three main components: (1) the basic principles of environmental change, (2) basic principles of biological response, (3) problems and procedures involved in assessing both of the above as well as their collective interaction. In considering such assessments, emphasis will be given to guidelines for the development of basic research efforts for providing useful and testable hypotheses concerning environmental change and biological response in areas eventually to be designated as Biosphere Reserves. The basic features of these component approaches and their collective interactions are outlined in figure 1.

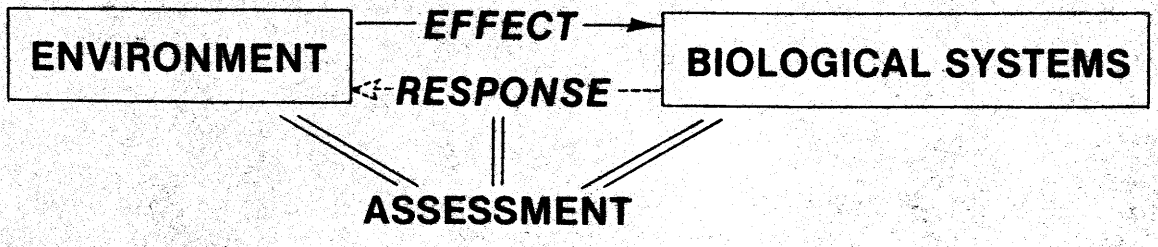

Figure 1.—Schematic representation of the assessment of the environment, the biological system and their interactions.

The concept of "environment" may be most usefully defined, for purposes of this discussion, relative to levels of complexity of organization of the natural world. The consideration of a gradient in levels of complexity of organization has been used in a fundamental sense to both establish the basic principles of ecology (Odum 1971) and to define the word "ecology" (Brisbin 1974). In this sense, the concept of "ecology" often simply defined as "the relationships between organisms and their environment," is simply expanded to the general case by defining the word "environment" as those levels of organization other than the one which is under consideration (fig. 2). This definition of the word "environment" may be applied to any level of biological organization. For example,

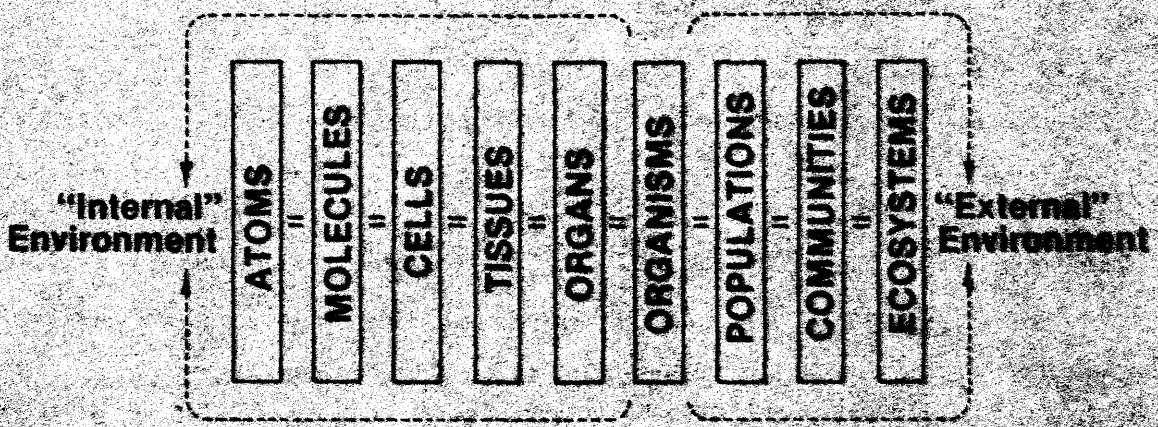

Figure 2.—Consideration of the concept of "environment" as being those levels of organization of the natural world other than the one under consideration. An individual organism, for example, has both an internal and external environment, consisting respectively, of less complex and more complex levels of organization (after Brisbin 1974).

a cell in a human liver, like a deer in a forest, has both an internal and external component to its "environment," consisting of those levels of organization which are, in each case, less and more complex than the particular level of organization being considered. The concept of levels of complexity of organization of the natural world will be used in this discussion both to define the concept of "environment" as well as to provide a frame of reference for a later discussion of the concept of biological responses to environmental change.

Three characteristics are important in relating biological response to environmental change: (1) *Magnitude* of change, (2) *Pattern* of change, and (3) *Rate* of change. Pattern and rate deal with the problems of relating and defining the processes of environmental change in terms of space and time. Similar considerations of both time and space should also be incorporated into analyses of biological

responses and the procedures for the assessment of both environmental change and biological response.

Of the three main characteristics of environmental change outlined above, it is undoubtedly those characteristics of rate which are the most important in determining the exact nature and extent of consequential biological response. Moreover, as will be discussed later, it is also the characteristic of rate which will prove to be the most important feature in distinguishing the consequences of man-induced environmental change from those resulting from natural processes. Living systems, whether cells, individual organisms, populations, or entire communities, are usually capable of adapting to and thereby surviving most environmental changes if such changes occur gradually.

The extremes of temperature endured by living populations of microorganisms and various invertebrates inhabiting thermal springs and polar icecaps attest to the magnitudes of environmental change to which organisms can adapt through evolutionary processes over extended periods of time. Even small, rapidly occurring environmental change, however, may have profound impacts on organisms and populations. Frequently, changes in some environmental parameter such as temperature or humidity, which may only prove detectable in terms of the computation of long-term seasonal means or, for example, average daily maxima, may have profound effects on the breeding biology, growth rate, or other vital aspect of an organism's life history or other biological characteristics (e.g., Bryant 1974).

Studies of temperature tolerance in various organisms illustrate the importance of rate of change in determining consequential biological response. In particular, several studies (e.g., Brett 1970, Coutant 1972, Martin and Gentry 1974) have shown that exposure of certain organisms to gradual increments of temperature will result in acclimation to higher temperatures. Acclimation allows such organisms to endure a greater degree of heat stress than would have been possible if such a temperature increase had been delivered more suddenly without the preceding period of gradual acclimation.

At higher levels of biological organization, the related process of adaptation which occurs in response to gradual environmental change over relatively longer periods of time, has frequently been shown to allow populations and/or biotic communities to tolerate environmental changes of a magnitude that would not have been possible if such changes had occurred rapidly. Long-term geologic and climatic alterations are well-known examples of environmental changes which have occurred at a sufficiently slow rate to allow various populations enough time to make the evolutionary adjustments which were needed to survive under the new environmental regime. For example, small sustained increases in swamp water levels in certain parts of the Southeastern United States have apparently contributed to the death and destruction of entire cypress tree communities following the introduction of production reactor effluents into such areas (Sharitz et al. 1974). In these very same areas, however, much more drastic fluctuations in water level have occurred over geologic time, as the sea level of the Pleistocene Ocean gradually fell,

exposing the coastal terraces and sea floor as the present day southeastern coastal plain. Through this latter process, however, the more leisurely pace of environmental change (i.e., change in water level) allowed orderly successional changes in plant community structure to keep pace. Mortality responses of the resident communities were undoubtedly different from those produced by reactor-induced increases in water level, despite the much greater magnitude of the changes involved. In systems such as the Florida Everglades, however, fluctuating water levels are prerequisite to the maintenance of stability in the biological community (Kahl 1964). Thus, certain kinds of environmental changes may actually be stabilizing rather than disruptive to the community. In such cases, the stabilization of environmental conditions may result in significant alterations of community structure and function.

Besides being one of the most important aspects determining the ability of various living systems to survive environmental change, the concept of time or rate is also one of the most important features distinguishing between so-called "natural" environmental changes as opposed to those which have been created by man's civilization and technology. In certain respects, the environmental changes resulting from many of man's activities do not really differ in type or mode of action from naturally occurring environmental changes. One difference is that man-induced changes generally occur over a much shorter period of time. The process of floral and faunal species extinctions, for example, has commonly occurred throughout geologic time. There has recently been a documented increase in the rate at which species, particularly large vertebrates, have become extinct as a result of the activities of man. Moreover, man-induced environmental changes can act synergistically or concurrently with natural processes and further increase the effects of such changes. Studies by Krantz (1970) and Mosimann and Martin (1975) have demonstrated, for example, how increased predation pressures from Paleo-indians could have interacted with natural mortality factors to produce massive Pleistocene extinctions amongst many species of large game mammals inhabiting the North American continent.

The study by Mosimann and Martin (1975), moreover, emphasizes the importance of spatial considerations (pattern) and the interaction of pattern and rate in producing the observed extinctions of many of the large Pleistocene game mammals by early man. Had either the pattern or rate of human exploitation and hunting differed, it is possible that some biological response other than massive mammalian community extinction might have been observed, thus resulting in a vastly different mammalian fauna in present-day North America. In still other cases, rapid environmental changes produced by human activities may produce biological responses which are mediated through normal evolutionary processes most of which normally proceed at a more leisurely pace. The well-known case of industrial melanism is an example of just such a situation (Kettlewell 1956). Artificial selection by man through the process of domestication (Brisbin 1974) suggests one of the most extreme cases of the response of evolutionary process to environmental changes which have been instituted at a greatly accelerated rate as compared to more natural situations.

In many of the preceding examples, our focus has been on a complex of environmental factors such as climate. In a biosphere reserve it will be necessary to decide to measure a series of specific variables. It is impossible in this paper to list and rank all of the variables that should be measured at each site. This is partly because the objectives may be site specific and, thus, the rank order will vary accordingly. Nevertheless, we have listed a number of variables that should be addressed as potentially important and should be considered in regards to any long term research or monitoring program (table 1). The frequency of measurement should vary according to the magnitude of short term fluctuations. Extremely static variables should be measured less frequently. Certain variables can be easily recorded on a continuous basis with available instrumentation.

Certain Biosphere Reserves will require special environmental measurements because of their unique physical characteristics (e.g., deserts or glaciated areas). The mass and speed of glaciers are examples of this type of problem. In general, this type of variable falls into the relatively stable category in which small changes may have profound effects on all levels of biological organization. Some of the environmental measurements will have regional significance; and an attempt should be made to determine the extent to which this may be true, perhaps by correlational analysis.

The environment has both physical and biological components. An ecosystem is the biological community plus its physical environment and their interactions. In addition, a biological response can be viewed as an environmental change depending on the reference point of interest within the level of organization studied. For this reason it is not practical to completely separate biological responses from environmental changes, but each can be discussed separately as a class of phenomena. Biological response can be measured at any one of the various levels of organization (fig. 2). For our purpose we will be concentrating on the individual, population, and community levels. Responses at lower levels are frequently seen at higher levels of organization, although they may be expressed in a different way.

A shift in environmental conditions can elicit a variety of responses in the organisms (table 2). The response(s) triggered will depend largely on the type and magnitude of environmental changes and the organism's "limits of tolerance" to the specific environmental variables which have been altered (Odum 1971). An organism's genotype is a product of generations of natural selection and evolution. Hence, each individual is adapted to specific sets and ranges of temperature, oxygen concentrations, moisture, chemical concentrations, and other environmental parameters.

A shift to a different set of environmental conditions can have varying effects. At very low levels of intensity, an environmental perturbation such as pollution may have effects that are measurable only as increases in concentrations of the pollutant in the body of the organism. At higher levels of stress, changes in an individual's behavior patterns may become apparent. The growth rate of an organism

Table 1--Examples of potentially important environmental variables to be measured as part of baseline or monitoring studies[1/]

Variables	Frequency of measurement[2/]
I. Climatic	
A. Temperature	Continuous
B. Relative humidity	Continuous
C. Windspeed and direction	Continuous
D. Turbidity	Frequently
E. Suspended particulate matter	Frequently
F. Rainfall	
1. Pollutant concentrations	Frequently
2. Major cations and anions	Frequently
3. pH	Frequently
4. Amount	Continuous
G. Barometric pressure	Continuous
H. Solar radiation	Continuous
II. Hydrologic	
A. Water discharge	Continuous
B. Water levels	Frequently
C. Height of water table	Frequently
D. Temperature	Continuous
E. Turbidity	Frequently
F. Suspended sediment	Frequently
G. Major nutrients	Frequently
H. Trace elements	Frequently
I. Specific conductance	Continuous
J. Organics	Frequently
III. Soils	
A. Physical characteristics	Infrequently
B. Water content	Frequently
C. Major nutrients	Infrequently
D. Trace elements	Infrequently
E. pH	Frequently
F. Organics	Frequently

[1/] Only the physical aspects of the environment are considered in the table.

[2/] Frequently means a greater than daily time interval between measurements; infrequently means at least 1 year.

Table 2--Categorical responses of 3 levels of biological organization to environmental change and parameters for their measurement and/or detection

Level of organization	Category of response	Variables	Sample references 1/
Individual	Structural	Gross morphology	Valentine et al. 1973
		Microanatomy	Hinton et al. 1973
		Chemical composition	Zeller and Finger 1971, Ratcliffe 1975
	Functional	Physiology	Cairns et al. 1973
		Behavior	Cairns et al. 1973, Poels 1975
		Development	Nelson 1974, Christy et al. 1974
Population	Structural	Abundance	Ehrlich et al. 1972
		Age composition	Hassler 1970
		Sex ratio	Klein 1965
		Genetic structure	Bonnell and Selander 1974, Selander 1976
	Functional	Reproductive rate	Ferens and Murphy 1974
		Survivorship	Pough 1976
Community	Structural	Species diversity Indices	Wilhm and Dorris 1968 Cairns et al. 1973, Haedrich 1975
		Percent similarity	Haedrich 1975
	Functional	Productivity	International Biological Project Handbooks

1/ References are examples rather than all inclusive.

can be enhanced or diminished by a change in its environment. Environmental stress may cause abnormal development and growth (Valentine et al. 1973). If perturbation results in a shift of one or more factors to levels outside the individual's tolerance limits, the organism must either emigrate or die.

A species population may respond to an environmental change with an increase, decrease, or no change in numbers or quality of individuals. Assuming movement in and out of a population to be approximately equal, then differential reproduction and mortality are the immediate reasons for change. Density, reproductive rate, and survivorship are important variables for study. Since these variables do show considerable change over short time periods, it is necessary to take a long range view to detect significant trends related to the overall health of the community. Certain species can be more easily studied than others in regards to these variables. Since our view in a Biosphere Reserve has to have a strong wholistic perspective and because it is not possible to study every species, a series of species should be chosen for study that represent different functional components of the system (e.g., carnivores vs. producers).

An additional criteria might be to choose "potential problem species" whenever possible. A "potential problem species" being one that might accumulate pollutants and become part of the food chain of man.

Quality of individual organisms may also change through time. For example, gene frequencies appear to fluctuate on an annual or longer term basis (Pimentel 1961, Krebs et al. 1973, Smith et al 1975). These types of changes can be especially important in judging the health of the biotic community and must be measured to determine the adequacy of the biosphere reserve concept. Let us suppose that one of the reserves is not sufficiently large to maintain genetic diversity either within or between species. A decrease in species number would be indicative of this situation, but decreases in genetic variability within species may be the earliest warning of restricted gene pools. Survey methods now exist for such measurements to be made on a variety of species (Smith et al. 1976). Other indices of population quality might be related to age structure, movement patterns, dispersion, flow of materials, and body composition and condition. There are many technological problems in measuring these variables, but in many cases they are species specific and will not be covered here.

The presence or success of certain species populations has long been used as an indication of environmental conditions. The occurrence of a species indicates that the environment is suitable for that species. If the environmental requirements for existence of a particular species are well-defined and relatively restricted, the presence of that species indicates the general nature of the environment in which it occurs. This is the indicator species concept. While the concept of the indicator species has been widely employed, it has serious, inherent limitations. These have been discussed in detail by Gaufin (1973), Patrick (1973), Cairns (1974) and Wuhrmann (1974). A major criticism of these authors is that environmental conditions other than the specific variables of interest may prevent the occurrence of an organism. In addition, the presence of an organism can be precluded by factors other than environmental suitability. For example, the species may not have had the opportunity for colonization of the area. When species are found for which detailed tolerance information is available, the information should be used.

Recently, biological assay techniques have emerged which utilize characteristics of a population other than its presence or absence to assess environmental changes. Valentine et al. (1973) used fluctuating asymmetry of three marine fishes as a measure of environmental stress resulting from pollution. Fluctuating asymmetry was defined by Valentine et al. (1973) as random deviation from perfect symmetry of any bilateral character and was thereby utilized as a measure of environmental perturbation. Certain species populations may also be employed as indicators of heavy metal contamination of the environment. For example, total mercury concentrations in tissues of piscivorous fishes are considered the best indicators of mercury pollution in aquatic systems (Zeller and Finger 1971). Similarly, analyses of lead concentrations in mosses and grasses provide a reasonable indication of changing atmospheric lead content

(Ratcliffe 1975). In addition, it may be possible to assess the concentration of a contaminant in one component of community and predict its concentration in some other component (Anderson et al. 1973). The use of organisms as bioassays or environmental pollution or stress is currently an area of intensive and promising investigation.

Multispecies responses to environmental changes are manifested at the community level. The observed responses can be structural, functional, or both. A structural response implies a shift in species composition or relative species abundance in the community. A functional response involves changes in features such as productivity and rates of nutrient transfer and energy flow. The structural attributes of communities have traditionally received more attention from ecologists than the functional aspects (Odum 1962). This is largely because the study of function is more difficult than the study of structure. In addition, ecologists have only recently begun to appreciate the importance of understanding rates as our view of nature has evolved from a static to a dynamic one.

Biological communities typically undergo natural changes in structure during ecological succession (Odum 1969). An environmental disturbance or perturbation results in a shift in the species composition of the community, usually to an earlier successional stage. For example, natural disturbances such as fire and windstorms revert forest vegetation to earlier stages of succession (Loucks 1970, Wright 1974). In aquatic and marine plankton communities, changes in the algal flora generally accompany temporal shifts in availability of nutrients (Patrick et al. 1969, Hutchinson 1973, Welch et al. 1975, and Pomeroy 1975). The nutrient enrichment or eutrophication of lacustrine environments results in increased standing crop of the phytoplankton community (Bachmann and Jones 1974, Schindler and Fee 1974, Welch et al. 1975) and a shift in dominance from diatoms and green algae to blue-green algae (Hutchinson 1973, Welch et al. 1975).

An additional community response to perturbation or stress is a reduction in species diversity (e.g., Paine 1966, Tsai 1973, Haedrich 1975). Hence, many investigators favor use of diversity measures in the biological assessment of pollutional stress (Cairns 1974, Haedrich 1975). A diversity measure, however, indicates nothing of the species composition of a community. Changes in species composition of a community can occur without corresponding changes in diversity. Haedrich (1975) has overcome this problem by using a measure of species overlap (percentage similarity) in conjunction with a diversity function to assess spatial and temporal shifts in community composition. This results in a powerful assessment of environmental pollution when seasonal changes in diversity and species composition are considered. A recent review of species diversity measures and the assumptions underlying their application has been presented by Peet (1974).

Natural succession of biotic communities is accompanied by functional as well as structural changes. For example, Loucks (1970) observed increases in both productivity and diversity during succession

of temperate forests. After the climax was reached, both diversity and productivity were diminished. There are many general hypotheses concerning functional changes in communities during succession (Odum 1969). Most of these have had little study, however, and many are subjects of considerable debate.

Altered productivity frequently results from an environmental disturbance or perturbation. Addition of toxicants may decrease community productivity (Whitworth and Lane 1969), whereas increasing the supply of limiting nutrients to a community will increase productivity (Schindler and Fee 1974, Tamm 1975). The casual factors altering productivity may initially be subtle and not readily apparent. For example, increased productivity of aquatic communities can result from remote manipulations or disturbances within the watershed which result in increased rates of nutrient supply (Bormann et al. 1974, Dillon and Kirchner 1975).

A new view of natural disturbance and community succession is beginning to emerge in the management of large, forested wilderness areas. This view is that most temperate forests may not have reached true "climax" because of recurring natural perturbations (mainly fire) which periodically reverted the community to earlier successional stages (Loucks 1970, Wright 1974). Under man's protection fires are suppressed, however, and the frequent natural perturbations, however, under which these communities developed are largely prevented. Continued protection allows persistence of a climax state and accompanying decreases in community diversity and productivity. Loucks (1970) and Wright (1974) convincingly argue that these systems should be allowed to undergo periodic natural perturbations to maintain the diversity and productivity of the communities. They suggest that elimination of natural perturbations may be the most disturbing effect of man on wilderness areas.

The first attempt at quantitative definition of various types of relative stability was made by Lewontin (1969). Webster et al. (1975) more recently defined two components of relative stability, resistance and resilience. Resistance is the ability of a system to resist displacement. Resilience is the ability of a system to return to a reference state once displaced. Since we are concerned here with biological responses to environmental changes, our focus will be on the resistance component of stability.

Stability of ecological communities has traditionally been associated with species or food web diversity. In an extensive review of the literature in this area, however, Goodman (1975) concluded that the theory of diversity-stability relationships in ecology is without substantial empirical or experimental support. What then, are the attributes of a community which determine its resistance to perturbation? The following discussion will, for two reasons, center on studies of nutrient cycles. First, the activities of man have had a marked effect on cycles of elements at both local and global scales. Man-caused alterations in rate of nutrient supply are common in nature. Second, as Duvigneaud and Denaeyer-De Smet (1975:151) state, "Mineral cycling is one of the most important parameters in the analysis of ecosystems,

because mineral elements, as many as energy and water, are essential to maintain the continuity and stability of these systems."

Pomeroy (1970 and 1975) associates relative stability with availability of nutrients or size of nutrient reserves. After comparing stability and nutrient regimes of four marine systems, coral reefs, oceanic plankton communities, subtidal eelgrass (*Zostera*), meadows and cordgrass (*Spartina*) communities, Pomeroy (1975) concluded that the relative stability of these four communities was much more easily related to availability of essential elements than to species diversity. Applying computer simulation techniques, Webster et al. (1975) examined stability of model ecosystems and reached similar conclusions. Model resistance to perturbation was positively correlated with size of nutrient storage compartments.

Observations on oligotrophic lakes provide additional empirical support for Pomeroy's hypothesis. By definition, nutrient pools in oligotrophic systems are small. Rate of primary production by the phytoplankton community during daylight hours is closely coupled to changes in the rate of supply of some limiting nutrient(s). Whole-lake experiments by Schindler and co-workers involving fertilizer additions to Canadian lakes have clearly shown that addition of phosphorus alone is sufficient to cause eutrophication (Schindler and Fee 1974, Schindler et al. 1975). Once made eutrophic by fertilization, the phytoplankton community is much less responsive to additions of nutrients (Schindler and Fee 1975, Schindler et al. 1975). Rate of phytoplankton production in culturally eutrophied lakes may ultimately be dependent on rate of influx of carbon dioxide from the atmosphere. Hence, phytoplankton production is most rapid for 2-3 hours following sunrise and undergoes a strong duirnal cycle in nutrient enriched lakes (Schindler and Fee 1975, Schindler et al. 1975).

Further investigations of nutrient cycles will undoubtedly provide additional insights concerning the stability of ecological systems. The importance of nutrient cycles will need to be determined for communities within the Biosphere Reserves.

As pointed out above, changes can occur at all levels of organization but must be documented. The general problem of assessing changes in a biological system through time and space has several facets. Of primary importance is the variance of the variable and the desired confidence interval for the measurement. As the confidence interval gets smaller or the variance larger, the number of replicates increases dramatically (table 3). Under certain circumstances the number of replicates could be excessively large. The desired confidence interval should be set *a priori* but is usually increased when the variance is found to be large relative to the mean. This results in a reasonable sampling schedule given the financial and personnel limitations inherent in most programs.

These considerations are further complicated when we are interested in documenting a spatial pattern or rate of change. Multiple samples through space or time are necessary, and the sampling interval is very important. With a good design and knowledge of the

Table 3--The number of samples necessary to achieve a certain confidence interval (C. I.) as a function of the coefficient of variation (C. V.) of the data. The C. V. is equal to the standard deviation (S) divided by the mean ($\bar{X}$) times 100 while C. I. equals two standard errors expressed as a percentage of the mean or $(2S/\sqrt{N}/\bar{X})\cdot 100$, where N is the number of samples

Confidence interval - %	Coefficient of variation*					
	5	10	25	50	75	100
1	100	400	2,500	10,000	22,500	40,000
5	4	16	100	400	900	1,600
10	1	4	25	100	225	400
25	1	1	4	16	36	64
50	1	1	1	4	9	16
75	1	1	1	1	4	7
100	1	1	1	1	2	4

*Samples of one cannot be used to calculate a confidence interval and should be used only as an indication of the low number of replicates required.

process, the rate function can be calculated with as few as six well chosen samples. Of course fewer samples may suffice but usually more than six samples would be required. If the pattern is a spatial mosaic, then replication on a site and increased distance between sampling locations will allow efficient partitioning of the variance. If appropriate community variables are measured at each site, then correlation and/or regression analyses become possible resulting in statistical statements concerning intra-community relationships. Ratios for the distribution of trace substances across trophic levels may be fairly constant in a variety of communities (Anderson et al. 1973). Changes in these ratios may be important indicators of shifts in trophic functions.

Our view of biological response must not be naively simple. Ecology is complex, and data collecting schemes should be designed to evaluate the importance of interaction and possible synergisms between variables in addition to their simple effects. This necessitates the use of multivariate statistical methods in addition to more complicated analysis of variance models. Lastly, all effects should not be expected as changes in mean values of some biological response. For example, certain environmental changes may result in disruptive selection, which would be expected to change the frequency distribution and increase the variance of the data. Trace contaminants are probably not normally distributed in biological systems (e.g., Pinder and Smith 1975) and calculation of the form of the frequency distribution draws attention to the first four moments of the data (mean, variance, skewness, and kurtosis). The form of a distribution may change under different environmental conditions or at different levels of biological organization (Pinder and Smith 1975).

The plan for collecting data in a Biosphere Reserve must be based on an understanding of techniques for calculating confidence intervals and changes that might be expected just as a result of the management of a reserve. For example, exclusion of fire could have profound effects and alter successional patterns in the reserve. Effects due to management of the reserve need to be delineated from other effects that might be due to the general deterioration of the environment either on a local or regional scale. Unambiguous assessment of biological change as an indication of environmental quality could be essential to man's survival in the face of expected technological impacts on the earth.

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Biosphere Reserves—Strategies for the Conservation and Management of Forest Gene Pool Resources

by

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INTRODUCTION

It is generally agreed that Biosphere Reserves offer a unique and often the only means of protecting, conserving, and maintaining a large diversity of ecological systems of varying sizes and complexities for current and future studies. Biosphere Reserves offer the ecologist a proven baseline, a reference point, on which to develop concepts related to the dynamic changes associated with evolving natural systems. In fact, most ecologists consider Biosphere Reserves as enlarged protected natural systems, and such areas are needed for research if we are to develop an understanding of the functioning and productivity of the large complex ecosystems.

To foresters who are interested in the maintenance as well as the long-term genetic improvement of the forest crop, Biosphere Reserves offer both a new opportunity in advancing the science of forest tree improvement as well as a much needed built-in safeguard for maintaining genetic diversity of forest trees which are subject to both extensive and intensive forest management.

Many different events during the last few years strongly suggest that forest geneticists must be concerned in ensuring an adequate and broad genetic base for forest trees if forestry is to avoid the errors of genetic erosion all too common in general agriculture (Barber and Krugman 1974, Maini 1973, Yeatman 1972). Over the centuries we have seen the risks that are involved when crops are built on a narrow genetic base. Outstanding examples include the potato blight and the subsequent potato famine in Ireland in the 1840's, the pear decline on the West Coast of the United States during the 1960's caused by a susceptible root stock, the common wheat rusts wherever wheat is grown, and most recently, the corn blight in the eastern United States in 1970 (National Academy of Sciences 1972, Barber and Krugman 1974).

Worldwide utilization of forest resources as well as forest land conversion for agriculture and urbanization are increasing. In most countries forest practices are becoming more intensive, and few forest stands will remain untouched. In many countries the native forests are being removed at a rapid rate and are often replaced by exotics or non-local reforestation stock with an indiscriminate mixing of often unrelated gene pools during reforestation (Maini 1973). This further erodes our ability to recover stable

and well adapted parental lines. It is necessary to maintain ancestrial genotypes as well as a broad genetic basis for future selection and breeding programs. Mixing of natural gene pools must be restricted (Yeatman 1972). Who knows what genotypes will be needed in the future? We must minimize the dangers of possible permanent genetic losses in a forest system.

Our strategies for meeting these issues must be based on a clear understanding of the genetic variation associated with forest trees. In addition, it must clearly be understood that forestry problems associated with maintaining a genetic base are not identical to general agriculture. Proposed solutions certainly will vary from those now being attempted in horticulture and agronomy (Hawkes and Large 1973).

GENETIC VARIATION IN FOREST TREES

It is generally recognized and accepted that forest trees have evolved inherent adaptations to a series of environmental factors at the site where they grow (Callaham 1970, Yeatman 1972). Research in the last 100 years has clearly shown that diverse environments throughout the range of a tree species leads to a genetically variable species. Similarly, widespread species tend to be more variable than restricted species. Often patterns of inherent variation parallel patterns of environmental variation (Callaham 1970). Likewise, races of a species growing in different climatic regions may differ in inherent adaption to environmental factors. Still, limiting factors generally are not always the same for cohabiting species (Callaham 1970).

More recent studies show that for native species local seed sources are best adapted but not always the most productive (Callaham 1970). In many areas of the world, however, there is inadequate information about the proper seed source to employ due to a lack of testing; and local seed sources must still be employed. In fact, in the absence of better information, conservative forestry programs are still solely dependent on a local reliable seed source. With provenance research and testing, preferred seed sources are being identified and recommended for use. Often provenance research is conducted to establish the credentials of exotic populations in those locations lacking a sufficient number of commercial species.

It is apparent then that if forestry is to avoid the loss of the original genetic base, strategies must be developed to maintain a reliable and varied genetic reservoir for future improvement, to provide standards for progress in improvement, and to ensure and perpetuate selected large or small populations for future mass seed production (Maini, Yeatman, and Teich 1975; Yeatman 1972). Even if we were only concerned with shortrun situations, the maintenance of the integrity of current populations of selected and proven seed collection areas is a serious problem. This is not an abstract problem to be confronted at some future date. Virtually all nations with active forestry programs are now encountering this problem. We need to assist and offer possible solutions to these difficulties.

CURRENT EFFORTS OF FOREST GENE MAINTENANCE

At this point, I hope that I have not left you with the impression that nothing has been done to protect the forest gene resources. To the contrary, various programs are in progress (Barber and Krugman 1974). Among the more common protective methods are:

1. *Seed, pollen, and tissue culture storage.*--Once forest tree material has been selected, it is feasible to maintain certain biological material as seeds, pollen, and more recently, tissue culture by means of various forms of storage--a method which is common to general agriculture. Obviously, when this method is employed, a decision has been made as to what is unique or superior. Our needs often change and so will our selection criteria. This method is also limited in scope since at this time not all material can be stored. Storage obviously leads to a static development in genetic composition since normal selection and evolution is halted (Wang 1975).

2. *Seed stands and plantations.*--A common practice is to set aside selected stands or develop plantations for future seed collection. Essentially, these represent only relatively small areas and can be employed to guarantee only limited genecological groupings.

3. *Seed orchards and arboreta plantings.*--These methods provide a means for maintaining genetic selections. As with storage, these methods are static and assume future needs. They do not permit normal evolution and commonly are relatively small in size.

4. *Research and Ecological Natural Areas, National Parks, Primitive and Wilderness Areas.*--These areas are set up for a variety of reasons, often for recreation purposes. Unfortunately, they are rarely established or managed for maintaining a broad genetic resource which is needed in forestry. They do provide a form of germ plasm conservation and certainly are needed and useful in the broad development of a germ plasm conservation program. Since the major use of these areas often precludes disturbances and commercial activities they are not suitable for mass seed collections and related activities needed in production forestry (Yeatman 1972).

BIOSPHERE RESERVES AS GENE POOL CENTERS

Should the limits placed on Research Natural Areas, or a wilderness not also apply to Biosphere Reserves? No, not if we consider Biosphere Reserves as a dynamic system whose purpose is to meet a number of well defined ecological situations. In the broadest meaning Biosphere Reserves can be used for (a) preservation, (b) conservation, (c) directed management. Thus, a given Biosphere Reserve should include both static and dynamic systems. Obviously, the same portion cannot and should not be used for all purposes.

How then can a Biosphere Reserve be structured to meet the current and future needs of forestry? First, to be effective the Biosphere Reserve must include forest ecosystems which are representative of forest gene pools commonly found in areas where

consumptive forestry is practical and will be practiced. Second, the Biosphere Reserve must be sufficiently large so as to reflect a full range of biological and environmental diversity. Third, it should be possible within the Biosphere Reserves to manage and manipulate given forest ecosystems. Finally, it should be possible to make both small and mass seed collections for consumptive forestry purposes.

It is rather obvious, if Biosphere Reserves are to be employed in advancing the science of forestry, that they must be representative of forests in which consumptive practices are employed. Their selection criteria should include this element whenever possible. Otherwise, studies and maintenance of Biosphere Reserves will become merely an academic exercise in terms of modern forestry.

The gene pool of natural forest population is in adaptive and dynamic balance with a given environment and can only be maintained through successive generations within the environmental context in which it evolved (Yeatman 1972). Since patterns of inherent variation of forest trees reflect patterns of environmental variation, it is essential that as many patterns of environmental variations are included in a Biosphere Reserve system. Thus, their size should reflect the extent of the biological and environmental variation encountered and they must encompass extensive forested areas. The area should also be sufficiently large to minimize the hazard of foreign pollen contamination. Included should be those stands which are highly unique and exceptional in growth and form as well as the typical representative stands of the area. In addition, the sensitive and often unique transition zones of the various species should also be included. Distinct forest tree populations threatened with destruction should be part of the Biosphere Reserve. We desire to "capture" as much of the gene pool as possible.

Many of the current attempts at gene pool conservation are static systems. They are directed at arresting the present rate of evolution, i.e., permit fire control. Similarly, all too often under undisturbed forest conditions shade intolerant species are at a distinct disadvantage and can be eliminated (Maini, Yeatman, and Teich 1975; Yeatman 1972). Yet many of these same intolerant species are a major source of current and future supply of wood and fiber. It should be possible by proper management, i.e., fire, logging, planting, to repeatedly maintain a segment of a Biosphere Reserve in a halted successional sequence.

We noted earlier that there is a serious problem of recovering and maintaining proven seed sources. By permitting mass seed collections, the genecological pedigree of a seed source can be guaranteed which in this day of declining intact gene pools is rather important to modern forestry. In essence, selected portions of a Biosphere Reserve would serve as a tested, reliable, and varied genetic reservoir for perpetuating selected populations for forestry. In fact, certain portions of the Biosphere Reserve should be preserved intact after the initial screening has taken place.

These recommendations for possible forestry uses of the Biosphere Reserves are not in conflict with the general philosophy of the system. To the contrary, the Biosphere Reserve effort is strengthened if the system can meet these forestry challenges in gene pool management.

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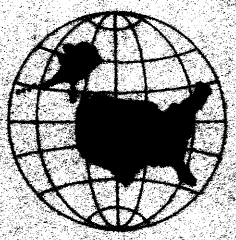

Thoughts on the Optimum Size of Natural Reserves Based on Ecological Principles

by

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Living organisms on the surface of the earth provide a unique source of genetic information unavailable in any other form for human exploitation.

In addition, the association of species into natural communities represents a unique series of coevolved systems representing the functioning of ecological laws which humans must understand in order to determine their ability to be a part of or regulate such systems for human advantage.

Scientists are now asking questions related to the preservation of ecosystems and their component species. Two questions of general interest are, (1) how big must an ecosystem reserve be to maintain its general community and species content integrity, and (2) how many replicates of these communities must we maintain to assure the continuance of all genetic lines.

It is interesting that the answers to these questions probably rest at the intersection of two bodies of knowledge--community ecology and the recently formalized theories of island biogeography (MacArthur and Wilson 1967).

The aspects of community ecology which are of particular interest fall into what might be called the species diversity-stability model. In its simplest form the paradigm predicts that in some manner the inherent stability of a community increases as the count of included species increases.

Such a simple construct of the relationship between these two phenomena is misleading. Whittaker (1975) and Orians (1975) list nine possible meanings of the word stability. Auclair and Goff (1971) indicate several ways to calculate a number representing species diversity. If the computation and definition problems were not sufficient, the correlation itself may not always hold; i.e., some species-poor ecosystems may have a high degree of some types of stability, e.g., the "robustly enduring" simple systems of May (1975).

I define stability as the maintenance of the ecosystem's equilibrium integrity in the face of perturbation. I realize that stability can be due to the diversity of species or the internal organization of the component species, or both. A similar position is expressed

by Van Emden and Williams (1974). In addition, I define species density as the number of species per unit area, and species diversity will include consideration of both abundance and equitability.

With these operational definitions set, let us discuss the problem.

AREAL EXTENT — SPECIES NUMBER

Studies of islands (MacArthur and Wilson 1967) suggest that the number of species/unit area may be approximated by the formula

$$S = CA^z$$

where S = number of species on an island; A = island area; C = a parameter characteristic of the particular taxon and archipelago of interest [synonym of *So* in Diamond (1975)]; z = a power assuming values in the range 0.18-0.35 (Diamond 1975) and approximated *a priori* by assuming that species abundances are distributed in a lognormal manner (Preston 1962).

We may use this relationship to infer the optimum size of a nature reserve. If we have a certain number of species, we simply calculate the area necessary to maintain them. The obvious point of difficulty is that the calculation requires estimates for the values of z and C.

The lognormal approximation for z is certainly reasonable considering the plethora of data suggesting its utility.

C then is the community specific constant which we must obtain. It is not clear what the absolute value will be for particular communities (I am currently attempting this), but some of the factors affecting C are of interest.

Generally C will vary depending on the taxon involved and the community type it occupies. The problem revolves around the inclusion of sufficient individuals of the species in question and their required symbionts to maintain populations above the critical breeding density. In some communities, individuals of species are sufficiently abundant that the per area redundancy of community components is high enough to maintain adequate populations without vast areal extent. The members of urban yard communities may be of this type, i.e., few species, generalists, small size, high densities, horizontal homogeneity. Thus, in a small area one may have a functioning example of a community type with all of its internal structure, e.g., energy flow (Falk 1976).

Communities composed of vagile, specialized, rare, sensitive, large-sized species and lots of them in a complex (heterogeneous) environment may require large areas to maintain their integrity.

Wilson and Willis (1975) refer to this in part under what they term truncation of ecological guilds, i.e., the early loss of specialists and large species on islands.

The obvious solution in a practical sense is to study and meet the needs of the species in the community of interest which has the greatest areal requirements. For communities as a whole, the island biogeography rule of thumb is that it takes a 10-fold increase in area to house twice as many species.

It is important to suggest here that species area curves and other types of calculations may also be appropriate. No one knows how far we may generalize from water-bounded islands to the community patch "islands" of terrestrial systems.

NUMBER OF REPLICATES — EXTINCTION

For each of the established reserves, one must remember that while its areal extent may be appropriate for the general maintenance of its component species, there is a tendency for species to become extinct. The implication of this fact is that replicate reserves of equal size must be used.

Terborgh (1974) uses the simple equation,

$$-\frac{dS}{dt} = kS^2;$$

where, $-\frac{dS}{dt}$ = rate of species loss; S = number of species, and k = coefficient of extinction, to estimate species loss.

The coefficient of extinction for various groups is derived empirically by the formula

$$k = \frac{-\frac{1}{S_p} - \frac{1}{S_o}}{t};$$

where, S_p = number of species present at any time; S_o = initial number of species.

The absolute value of k depends, in part, on the pressures exerted by competing species; and thus varies from place to place. A nature reserve surrounded by a totally different community may be constantly bombarded with potential competitors and thus may have a high species replacement rate, while an isolated area with few infiltrating competitors loses species at a lower rate.

The consequences of these relationships has caused several workers to posit about the appropriate shape and numbers of nature reserves (Diamond 1975, Wilson and Willis 1975).

Figure 1 depicts several postulates derived from such thinking. Note that two simultaneous principles are involved in reasoning about these arrays. First, a circle has the highest area per perimeter ratio and thus should always be less susceptible to outside influences assuming such influences are related to perimeter extent. Second,

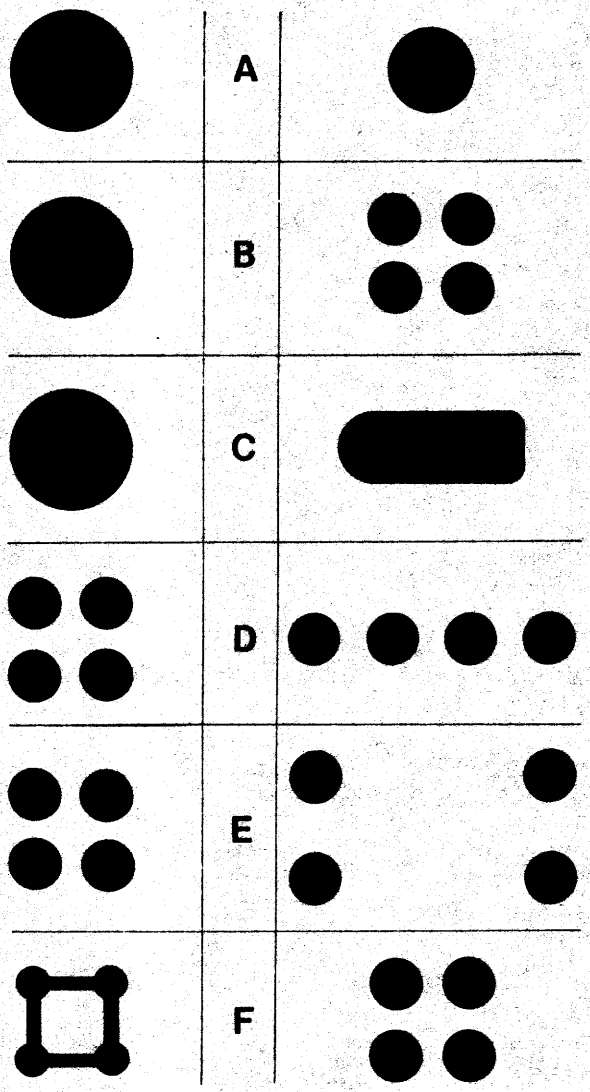

Figure 1.—Geometric relationships of reserves based on biogeographical principles (after Diamond 1975, Wilson and Willis 1975). Relationship in the left hand column is always more desirable than that in the right hand column. A. Larger reserve better than small, B. large reserve better than four small ones of equal total area, C. circular reserve better than any other shape, D. mutually adjacent areas better than linearly arranged, E. close replicate reserves better than distant ones, F. smaller but connected reserves better than separate but equal area reserves.

close, or better yet, connected (archipelago) replicates are superior because proximate similar areas act as replacement source areas for species to their homologues when extinction of species occurs. In addition, "invading species" are in reality the same species as the components of the invaded community.

PRACTICE

The approach to this point seems clear. First determine the minimum area necessary to maintain a community type. If in doubt, calculate the area for the most sensitive species (rare, large, highest trophic level, most vagile). Second, try to assess rate of extinction by determining the coefficient of extinction (k) for the most sensitive species. Then establish replicate natural areas making the practical trade-offs among size, number, and proximity. The ideal is a large number of large areas adjacent to and mutually interconnected.

The first consideration must be a sufficiently large minimum area. The second consideration would be to establish replicates, and the third, to establish these at proximate places.

The comments to this point imply that the higher the species density the higher the stability of the community and also that species number alone is the best indicator of required area.

These two assumptions need not be true. Stability of communities may result from several possibilities. The diversity-stability paradigm actually implies that species are interconnected and that stability results from this anastomosis. Communities of few species may consist of resilient members (broad ecological tolerances) and therefore resist the effects of perturbation. On the other hand, species-rich communities may have little biological coupling (coevolution) and therefore lack the stability of association.

Deserts seem to be composed of few highly resilient species. Rainforests may contain large numbers of species, but they are frequently specialized to the point of paralleling the precariousness of a parasite's mode of life.

Thus, to persist over the time axis a community must endure perturbation (resiliency) or have sufficient biological alternatives (redundancy) to fill roles as they are opened by extinction.

Despite the above counterintuitive relations of diversity and stability, deserts or rainforests (and all community types), wherever they are and whichever taxa comprise them, have startling similarities from mere physiognomy [e.g., Mediterranean scrub of Australia, Chile, California, etc., compared in Di Castri and Mooney (1973)] to interesting guild analogues (Pianka 1973; MacMahon 1976). This suggests that similar communities may be maintained with a similar management strategy regardless of their place of occurrence.

Since the best correlates for predicting community type are frequently abiotic factors, perhaps a starting point would be to determine optimum size and number from as few as the 30 "life zone" types (fig. 2) determined by Holdridge (1967). Holdridge's use of three environmental variables (annual precipitation, potential evapotranspiration, and mean annual biotemperature) to classify the entire earth is certainly a simple scheme--albeit somewhat too generalized.

The reduction of world variability to just thirty communities would allow us to use international cooperation to choose one example each of thirty types of vegetation, somewhere in the world, which would be examples of communities containing inherently unstable members. Scientists could then perturb such systems, derive "C" and from historical records perhaps estimate "k" and determine rational guidelines for conservation practices.

In the end, our ability to carry out this "ideal" plan will always be affected by "political" decisions. Nonetheless, in the long run we have no viable options other than to conserve examples

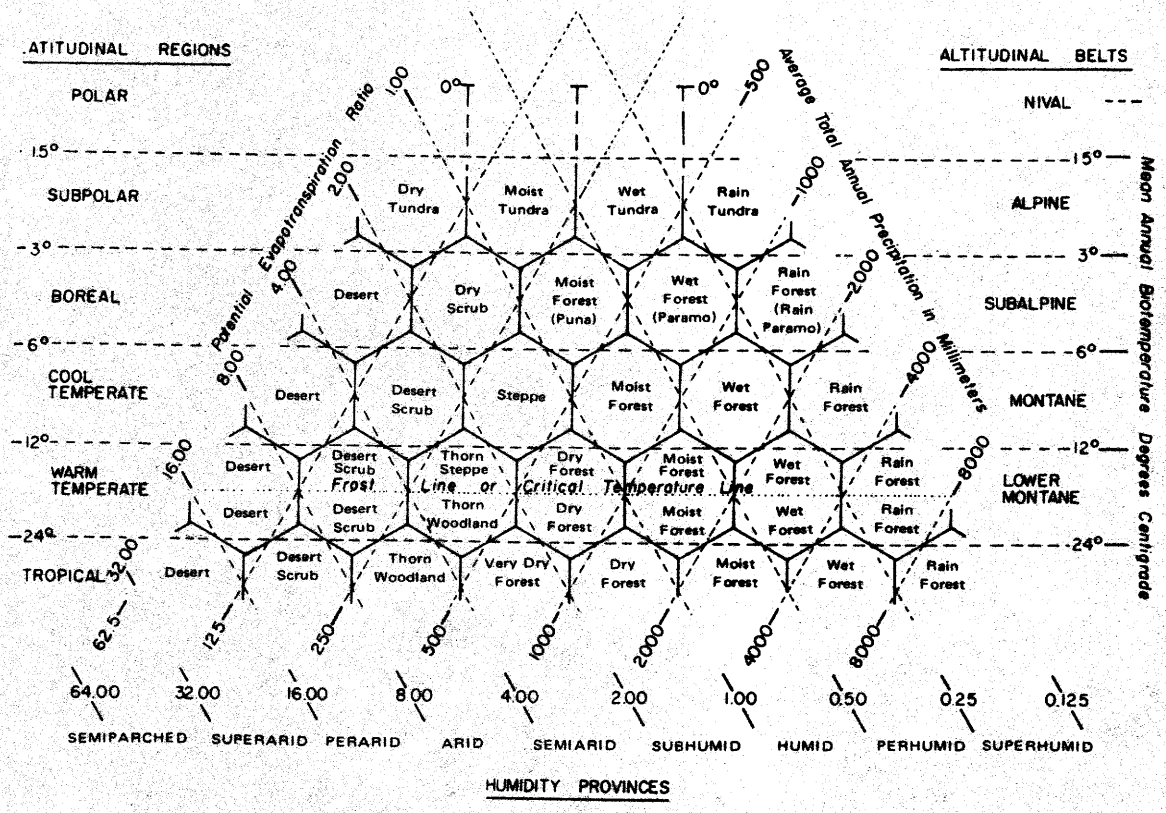

Figure 2.—Diagram for the classification of world life zones or plant formations (after Holdridge 1967).

of all species and ecosystems. Being a component of every world ecosystem, if man can not elucidate the systems' rules, his very existence is tenuous.

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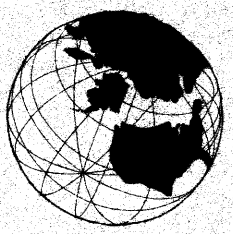
An International View on BIOSPHERE RESERVES and Their Uses

Cascade Head Scenic Research Area

Sequoia National Park



Thoughts on the Biosphere Reserve Concept and Its Implementation

by

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The popularity of (MAB) Project 8, "Conservation of natural areas and of the genetic material they contain," should not be a surprise. The topic is clearly one of universal appeal and importance. As natural ecosystems throughout the world are being altered on a massive scale, the importance of setting aside representative sites inclusive of the world's major ecosystem types can scarcely be questioned. The international network of Biosphere Reserves being developed within the framework of MAB Project 8 is intended to combine ecological preservation of representative ecosystems with research into the functioning of these ecosystems, investigations to analyze man's impact on natural systems, and development of the means to monitor this impact. Actually, Project 8 must constitute the backbone for the entire MAB program, by providing logistic support for such research. The provision of opportunities and facilities for education and training is an additional important function of Biosphere Reserves.

The Biosphere Reserve concept, first elaborated in MAB Report No. 22 (UNESCO 1974), has considerable flexibility and allows countries much freedom in adapting it to meet their specific needs. Although a variety of approaches are being taken, it appears to us that the concept is evolving to comprise the following major elements which distinguish it from complementary national conservation programs:

1. Emphasis on use of natural areas in research, including that which involves providing an improved scientific base for conservation;
2. Inclusion of man-modified ecosystems to serve as sites for comparative studies of natural and modified ecosystems;
3. Emphasis on conservation of ecosystems (with their full array of component species), rather than upon conservation of individual species;
4. Emphasis on providing sites for long-term continuity of research and monitoring;
5. Choice of sites for representativeness, rather than for uniqueness;

6. Provision for an international framework for cooperation among nations in conservation and research.

In summary, the establishment of an international network of Biosphere Reserves is a major endeavor in the field of conservation, unique in combining conservation, research, monitoring, and training and education elements and in linking protected areas in an international framework through the Man and the Biosphere (MAB) Program.

NATURAL AREAS AND RESEARCH

The need for a better scientific basis for biological conservation is consistently underestimated. It is true that conservation invariably involves many political, economic, and social considerations, but this is no justification for neglect of ecological theory in selection and management of sites. Inability of conservation area managers to provide for rational management often results in weakening of political support. A major cause of faulty management is lack of an adequate ecological information base. Improved ecological theory could contribute substantially to clearing political obstacles. Much more information is needed just to establish how much ecological preservation may be necessary or desirable. It is remarkable how poor the available information is. Advocates of ecosystem conservation are often badly handicapped by a very weak supply of the information necessary to convince governments of the need for conservation.

The esthetic, educational, scientific, cultural, and recreational values of natural ecosystems are generally well accepted but are understandably often regarded as luxuries both by developing and developed countries. The values of these areas as reservoirs of genetic material and for providing "public service" functions (term used by Biswas and Biswas 1976) are recognized only in a very general, vague way because they are far from being fully understood. "Public service" functions include provision for control of potential agricultural pests, pollination of domestic plants, prevention of erosion, etc.

What percentage of the earth's surface and of individual ecosystem types must be maintained as relatively natural ecosystems in order to provide for global and regional stability of the biosphere? Given the present state of knowledge, ecologists are unable to provide an answer. What percentage of the earth's species (and which ones?) must be maintained to allow for this stability? Although no answers to these questions are possible, considerations from the theory of island biogeography (MacArthur and Wilson 1967) suggest that if 10 percent of a given ecosystem type is preserved, no more than 50 percent of the species dependent upon this type can be preserved in the long run (Slatyer 1975). If this assessment is correct, there is clearly immediate cause for much concern. The present small percentage of the earth's terrestrial surface devoted to National Parks and other ecological reserves appears to be inadequate for preservation of species which are dependent on natural ecosystems, and most areas

outside parks and reserves may be eventually subject to modification by man. These are critical questions which have high scientific priority, but are rarely asked.

We fully recognize that the present Biosphere Reserve network is not comprehensive enough to make a major direct contribution to preservation of the earth's genetic material and sustained operation of public service functions provided by natural ecosystems. Only through a concerted international effort toward a better understanding of functioning of natural ecosystems and man-modified ecosystems can answers to critical ecological questions be obtained. Among key topics for investigation is the relationship between the natural and man-modified systems: How does the latter depend on the former for productivity? This complex question must be approached from many different directions. Answers will not necessarily be similar for such diverse ecosystem types as tropical rain forest, savannah, and temperate deciduous forest. We hope that research carried out in Biosphere Reserves will aid in leading to a satisfactory answer to such questions.

MAN-MODIFIED SITES FOR USE IN COMPARATIVE STUDIES

A major research activity associated with Biosphere Reserves should be the comparison of natural and man-modified ecosystems, with the aim of providing information relevant to development of modified ecosystems which maintain long-term productivity for man's benefit. In order to assure availability of man-modified sites which are properly comparable to the natural ecosystems being preserved, Biosphere Reserves should include various types of modified sites.

A Biosphere Reserve will ideally consist of a core area, devoted to preservation of natural or near-natural ecosystems, surrounded by a buffer zone which should consist of ecosystems grading from natural and semi-natural adjacent to the core area, to strongly modified. The various types of modified sites should generally be included in the outer buffer zone.

Another logistical possibility is to have the modified sites geographically separate from the main portion of the Biosphere Reserve. A variation of this latter possibility being developed in the United States is the cluster concept of Biosphere Reserves, which involves a separation of the primary conservation site and experimental site for a given ecosystem within the Biosphere Reserve program.

CONSERVATION OF ECOSYSTEMS

The emphasis within the Biosphere Reserve program of ecosystem conservation rather than individual species conservation is by no means new or unique but is highly significant. Efforts at conservation of individual species are important and worthy of support, but must be aimed at relatively few species which are conspicuous

enough to attract attention and to stir human emotions. Programs aimed at individual endangered species will not be able to cope with problems such as those posed by modification of large areas of tropical forests. The total number of animal and plant species on earth is probably somewhere between the 1.5 million species which have been described and the 10 million postulated on the basis of extrapolation of species--abundance curves (Myers 1976). A large percentage of these species, both described and theoretical, are plants and insects of tropical forests, many of which are highly susceptible to habitat modification.

Efforts at saving individual species have the merit of dramatizing the problems of extinction, and research on a relatively few species can serve to elucidate the principles of the species extinction process. In the long run, however, efforts must be concentrated on preservation of an optimal extent of natural and semi-natural ecosystems. In spite of the need for expanding agricultural production and energy resource exploitation to support the world's growing population at a high enough level that their basic needs are satisfied, adequate land must also be set aside to allow for preservation of species and essential public service functions which, among other things, make agriculture possible. Fortunately, land which provides for stability of the biosphere can simultaneously function to satisfy esthetic, scientific, cultural, educational, and (under particularly careful management) recreational needs of mankind. Unfortunately, it appears inevitable that a substantial fraction of the earth's species is going to be lost unless a better rationale for saving them (through preserving their habitats) can be quickly formulated and drastic measures implemented immediately to counteract trends which are under way in tropical forests and elsewhere. A realistic strategy, which recognizes the minimum complement of species which must be maintained, must be developed on a scientific basis.

PROVISION OF SITES FOR LONG-TERM RESEARCH AND MONITORING

MAB Report No. 22 (UNESCO 1974) specifies that research within Biosphere Reserves should be at three levels: investigation of the structure, functioning and dynamics of a particular ecosystem; comparisons between ecosystems; and comparison in time. For the latter type of research, assured long-term site protection is, of course, essential. Important studies of this sort involve documentation of long-term trends including ecosystem recovery following disturbance by man, fluctuations related to periodic natural disturbance (as impact of natural fire), and effects of year to year climatic fluctuations or of long-term climatic change. Studies of this type have been traditionally neglected because of the difficulty of assuring site security.

Important follow-up studies have been done to classic studies of ecological pioneers when, often by chance, the study sites have been left intact. The need exists to remove the element of chance. Even in National Parks, research sites used in the past have not always proved immune to alteration for development. In Biosphere Reserves,

research must be recognized as a major use having priority over other uses which might jeopardize research sites.

When research sites remain intact, it is often possible to build on previous studies carried out at a single site to accumulate a comprehensive body of knowledge concerning the site even though large amounts of money for research may not be available at any one time. Progress in theory or technology may allow advances to be made over previous work at a site. Where very comprehensive studies have been carried out, there is much need for preserving the sites for follow-up studies. With this philosophy in mind, sites used in the International Biological program, such as Pasoh in Malaysia, Lamto in the Ivory Coast, H. J. Andrews Experimental Forest in the U.S.A., and Solling in the Federal Republic of Germany, have already or will probably become Biosphere Reserves.

CHOICE OF SITES FOR REPRESENTATIVENESS

The emphasis on representativeness rather than on uniqueness in the criteria for Biosphere Reserve choice is another very important consideration and a major distinguishing feature between Biosphere Reserves and the traditional concept of National Parks. Although Biosphere Reserve criteria given in MAB Report No. 22 allow for selection by countries of unique areas, the emphasis must be on sites representative of major ecosystem types. Unique areas are probably justified for Biosphere Reserve designation only when a considerable research effort is under way and when the area has much value in comparison with unique or typical areas of the general type in other parts of the world.

National Park systems have generally been developed with an emphasis on the unique, spectacular, and beautiful--not on protection of representative ecosystems. Since spectacular and beautiful landscapes often correspond with representative ecosystems, there are many cases where National Parks are well suited for incorporation into the Biosphere Reserve network.

There are two major reasons for the emphasis of MAB Project 8 on representative ecosystems:

1. to provide conservation and research sites covering as broad a range of the world's biotic diversity as possible; and

2. to allow extrapolation of research findings throughout a large area.

Representative sites may be difficult to find in some cases where whole ecosystem types have been almost completely converted to agriculture. This is the case for grassland ecosystems of North America and Europe. Some forest biomes have been so thoroughly modified that large samples of relatively natural forest are difficult to find--e.g., the Mediterranean forests and maquis. When near-natural ecosystems of these rare types can be found and protected, they have great value as "baseline" sites for gaining understanding of functioning of natural systems as background for understanding agricultural systems and degraded lands.

PROVISION OF AN INTERNATIONAL FRAMEWORK

The MAB program and Project 8 are concerned with problems which are shared by all countries; and success cannot be achieved without a high degree of international cooperation, including assistance from developed countries to developing countries and cooperation among countries which share similar ecological conditions. Indeed, the prime reason for initiating the program was to promote this sort of cooperation. The Biosphere Reserve concept has been well received by many countries. The generally accepted goal for MAB 8 of eventual establishment of at least one functioning Biosphere Reserve in each of the major ecosystem types of the world appears to be a realistic possibility within (UNESCO) member states which are participating in MAB. This world-wide network is to be linked by cooperation in the exchange of information and personnel (both scientists and managers).

Although provision of this international framework is an important aspect of MAB Project 8, the limits to its international nature should be clearly recognized. A country's sovereignty is in no way affected by creation of a Biosphere Reserve within its territory. Each individual country participating in the program has the responsibility to provide protection for its own Biosphere Reserves by establishing and enforcing an adequate legal framework. Regulation of access and use of a Biosphere Reserve rests entirely with the country which establishes it. Scientists wishing to carry out ecological research within a Biosphere Reserve can do so only with permission of the appropriate authorities of the host country.

THEORETICAL FRAMEWORK FOR THE NETWORK OF BIOSPHERE RESERVES

As stated above a major goal of MAB 8 is eventual establishment of at least one functioning Biosphere Reserve in each of the major ecosystem types of the world. These sites are to be selected taking into consideration the following criteria (UNESCO 1974): 1. representativeness, 2. diversity, 3. naturalness, and 4. effectiveness as a conservation unit.

The criteria (UNESCO 1974) also allow for selection of "unique" areas and of "man-modified" areas, including "varied and harmonious landscapes" and "modified or degraded landscapes." The contribution of such sites to the MAB 8 program as a whole will depend largely on their value in research and on their comparability with representative natural sites of the network. Because of their specialized nature, they will not be considered further in this paper.

As a framework for the network of Biosphere Reserves, IUCN has recently produced, under contract with UNESCO, a publication by M.D.F. Udvardy (1975), which divides the world into 193 biogeographical provinces, based on physiognomy of vegetation and on floristic and faunistic differences between regions. Ray (1975) has produced a similar classification for coastal and marine ecosystems of the world. Although Udvardy's classification has many merits, a classification at this scale must be rather artificial and arbitrary so

that a reader with moderate knowledge of biogeography readily finds many details to criticize. Udvardy has, however, succeeded in providing an adequate theoretical framework for the network of Biosphere Reserves. Each of the 193 biogeographical provinces falls in one of 14 "biome types" and in one of 8 "terrestrial biogeographical realms," forming a biogeographical-ecological matrix as shown in table 1. When Biosphere Reserves have been established in most biogeographical provinces, the opportunity will exist for comparative studies between areas of the same "biome type" but in different "biogeographical realms."

Thus, Udvardy recognizes 18 major types of "tropical humid forest" --7 in South and Central America, 3 in Africa (including part of Malagasy Republic), 7 in the Indo-Malayan region, and 1 in Australia. Ideally, at least one Biosphere Reserve should represent each of these 18 biogeographical provinces. Each of these Biosphere Reserves would differ greatly from the others in fauna and flora, but all would share many characteristics common to all tropical humid forest. Management principles worked out in one of these areas would have potential for application in the other areas.

Most of Udvardy's 14 biome types can be further subdivided to provide better resolution in selecting areas for comparative studies. Some prime types for comparative ecological studies include regions with temperate rain forest (which share problems of maintenance of high quality watersheds subject to forest exploitation); regions with "mediterranean-type" sclerophyll vegetation (which share problems of fire management); and various islands with similar climate (which share problems of invasion by exotic species).

PRACTICAL ASPECTS INVOLVED IN IMPLEMENTATION OF MAB PROJECT 8

The fourth session of MAB's International Co-ordinating Council established a procedure according to which countries can propose areas for formal designation as Biosphere Reserves, through submission of information on the proposed areas in accordance with a standard format. Authority was delegated to the Bureau of the International Co-ordinating Council to approve or disapprove applications.[1/]

Experience during two years since a MAB Expert Panel established criteria and guidelines for biosphere reserve establishment (UNESCO 1974) shows that pragmatism is necessary in implementing MAB Project 8. For example, in selecting areas for designation as Biosphere Reserves, some countries have emphasized the conservation aspect of MAB 8, while others have emphasized the research aspect.

1/ At the meeting of the Bureau of the International Co-ordinating Council of MAB held in June, 1976, the first Biosphere Reserves--57 in number from 9 countries--were formally approved and will receive a certificate of formal recognition from UNESCO. Over 150 additional areas have been provisionally identified by countries for intended designation as Biosphere Reserves.

Table 1--Biogeographical-ecological matrix, showing numbers of "biographical provinces" for each of Udvardy's 14 "biome types" which occur within each "terrestrial biogeographical realm." (Based on Udvardy 1975)

Biome types	Terrestrial biogeographical realm								
	Nearctic	Palearctic	Africo-tropical	Indo-Malayan	Oceanian	Australian	Antarctic	Neotropical	Total
Tropical humid forests	--	--	3	7	--	1	--	7	18
Subtropical and temperate rain forests or woodlands	2	2	--	--	--	1	1	4	10
Temperate needle-leaf forests or woodlands	2	2	--	--	--	--	--	--	4
Tropical dry or deciduous forests (including monsoon forests) or woodlands	--	--	7	2	--	1	--	10	25
Temperate broad-leaf forests or woodlands and subpolar deciduous thickets	2	10	--	--	--	--	--	1	13
Evergreen sclerophyllous forests, scrubs, or woodlands	1	2	1	--	--	4	--	1	9
Warm deserts and semi-deserts	3	3	6	1	--	3	--	2	18
Cold-winter (continental) deserts and semi-deserts	1	4	--	--	--	--	--	1	6
Tundra communities and barren arctic desert	6	3	--	--	--	--	3	--	12
Tropical grasslands and savannas	--	--	--	--	--	2	--	4	6
Temperate grasslands	1	4	--	--	--	1	--	2	8
Mixed mountain and highland systems with complex zonation	3	9	5	--	--	--	--	5	22
Mixed island systems	--	2	3	12	7	--	--	9	33
Lake systems	1	2	4	--	--	--	--	1	8
Total	22	44	29	27	7	13	4	47	193

The largest and best potential sites for conservation purposes are often remote from scientific institutions, and there is a tendency to concentrate research efforts in relatively accessible areas. In some countries, the major representative ecosystem types have been largely converted to agriculture or degraded, so that the remnants available for preservation are not large and may not have intact complements of fauna and flora. Consequently, some large Biosphere Reserves are being established where research may not be carried out immediately. Some small Biosphere Reserves are being established where intensive research is under way. The majority of sites lie between these extremes.

The ideal situation would be to have large, well-protected Biosphere Reserves with comprehensive research projects in all biogeographical provinces. This is a worthy goal to work toward, but must not be followed over-zealously at this stage in the program. Emphasis must be upon getting functioning Biosphere Reserves established where countries have the willingness to establish them. Sites which clearly fail to meet the test of "viability as a conservation unit" (MAB Report No. 22 - UNESCO 1974) cannot be accepted as part of the world-wide network. "Viability as a conservation unit" is, however, a relative concept. Even some of the world's largest conservation areas fail to contain complete habitats for wide-ranging migratory mammals, while very small areas can serve as useful conservation sites for some sedentary species. Standards must be applied most leniently in ecosystem types where habitat modifications has been most widespread.

As far as the role of UNESCO and the MAB Secretariat in further stimulating the development of MAB Project 8 is concerned, the immediate priorities appear to be as follows:

1. Encourage countries to develop their own network to the fullest possible extent in accordance with Biosphere Reserve criteria to the fullest extent possible.

2. Encourage cooperative links between countries with Biosphere Reserves representing similar ecosystem types--including exchange of information and personnel.

3. Continue to work to ensure full-fledged support of international organizations, such as IUCN, (UNEP), and (FAO) for MAB Project 8. Development of the Biosphere Reserve network is one of the concerns of the "Ecosystem Conservation Group," formed in 1975, which is attended by representatives from UNESCO, IUCN, FAO, and UNEP and is chaired by UNEP.

4. With funds available, provide for assistance to developing countries to develop potential Biosphere Reserves into functioning Biosphere Reserves. A current project under way in Southeast Asia is giving initial experience in this type of activity. It will be necessary to actively seek funds from all possible sources to make MAB Project 8 a success in developing countries. Plans are under way to prepare proposals for cooperative efforts with IUCN.

In large measure, however, the successful evolution of the Biosphere Reserve network is dependent on the initiatives of individual countries participating in MAB. The initiatives taken by the U.S.A. and U.S.S.R. in development of MAB Project 8 and reported at the bilateral symposium have resulted in many new ideas and are welcomed enthusiastically by UNESCO.

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Soviet Views on BIOSPHERE RESERVES and Their Uses

Olympic National Park

H. J. Andrews Experimental Forest

The Biotic Diversity of the Northern Hemisphere — Problems of Study and Conservation

by

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Rational conservation of the flora and fauna should be preceded by regionalization of the water or land surface, i.e., the establishment of an hierarchic system of regions encompassing the entire land surface including internal bodies of water or the entire area covered by seas and oceans. This type of regionalization can only be carried out on a typological basis, i.e., every region differs from others by the range of plant associations and by fauna and flora; in other words, by types of biomes and biotas.

The problem of regionalization is also aggravated by the fact that the geographic distribution of biotas and biomes is determined by several groups of factors.[1/] Some of them are zonal in nature, others are non-zonal. The interplay of these factors creates the diversity of life conditions. Therefore, every region, regardless of its rank, is characterized by the combination of three types of associations: zonal ones which occupy elevated, well-drained upland soils of medium mechanical compositon; associations of intra-zonal character which do not occupy zonal environments but occur in several (or the majority) of the world's zones (e.g. marshes, solonchaks, solonetz, etc.); and extra-zonal or azonal associations which are zonal in a neighboring zone but are confined to an extra-zonal environment in the given zone (for instance, steppes on the southern slopes among forests: oak forests in steppe ravines, etc.). This pattern is complicated by the vertical zonation which differs in different mountainous countries as the result of their geographical position as well as aspect and steepness of slopes, extent of talus and rock exposure, etc.

It may be added that the structural and functional peculiarities of communities are primarily determined by modern ecological conditions while their flora and fauna depend equally upon more recent geological history. Owing to this, the factors which determine peculiarities of the biota, on the one hand, and the properties of the biomes, on the other, are dissimilar. This has provided the basis for suggestions that it is fundamentally impractical to develop a master system of regional categories for both the biota and biomes.

[1/] Biome is an aggregate of vegetation and animal populations. Biota is an aggregate of flora and fauna.

As indicated by A. F. Emelyanov (1974) there are, however, general regularities in the distribution of plants and animals (and, we may add, their associations). This phenomenon is determined by: (a) the fact that the same abiotic factors (the climate primarily) affect both plants and animals; and (b) biogeocenotic relationships in the distribution of plants and animals, which developed in the process of their coexistence and in the course of the biotic transformation of life conditions.

Thus, we consider (following A. F. Emelyanov) that the prevailing factors of organism distribution have many similarities. This allows the possibility (and the necessity) of developing a master general geographical scheme of regionalization. This certainly does not exclude the use of available data on the distribution of various groups to create particular charts of biogeographic regionalization. The charts based on some groups (angiosperms, for instance) may be applied in the analysis of the spread of other groups (insects, for instance). Regionalization based on relatively small taxonomic groups should be viewed, according to A. F. Emelyanov, as the material for building and improving general biogeographical regionalization charts.

We believe that it is possible to trace only large-scale delimitations on the distribution of vertebrates. Most of the representatives of this group have inter-landscape activity and only relatively few intra-landscape activity. Practically all invertebrates are confined to the smallest-sized natural, territorial complexes. The immobility of plants makes it possible to use them for regionalization at any level.

Thus, the joint regionalization of a biota and biomes is possible and necessary. The most recent efforts of compiling this type of combined regionalization were made by R. Dasmann (1974) and M. Udvardy (1975).

We believe that the regionalization system suggested by these authors may be taken as the initial document for compiling a coordinated international program of environmental protection measures. Our remarks refer to the dismemberment of only one biogeographic region - the Palearctic, most of which is within the U.S.S.R. and neighboring countries. R. Dasmann and M. Udvardy are not fully acquainted with data and concepts of Soviet specialists. This explains a number of inaccuracies in their draft subdivision of Palearctic into biogeographical provinces.

The idea of our chart is to preserve, as far as possible, the names and the boundaries of provinces singled out by R. Dasmann and M. Udvardy and to make alterations only where facts contradict the concepts of the mentioned authors. Similarly, we have preserved the order of coding the provinces suggested by M. Udvardy (I.I.I.): Biogeographical region (realm) - biogeographical province - the type of biome (table 1, fig. 1).

Table 1--Biogeographical Provinces of the Palearctic

Code	Name of biome	Type of biome
2.1.1.	North Eurasian	tundra
2.2.2.	Icelandic	meadow
2.3.2.	Kamchatkan	meadow
2.4.3.	West Eurasian	taiga
2.5.3.	East Siberian	taiga
2.6.3.	Okhotsk	taiga
2.7.3.	South-Siberian	mountain-taiga
2.8.4.	British	broadleaved
2.9.4.	Atlantic	broadleaved
2.10.4.	Central European	broadleaved
2.11.4.	North European	coniferous-broadleaved
2.12.4.	Iberian	mountain-broadleaved
2.13.4.	Central European	mountain-broadleaved
2.14.4.	Balkan	mountain-broadleaved
2.15.4.	Black Sea-Caucasian-Girkan	mountain-broadleaved
2.16.4.	Amur-Manchurian	coniferous-broadleaved
2.17.4.	Central Chinese	broadleaved
2.18.5.	Mediterranean	evergreen hardleaved forests
2.19.5.	Atlass	evergreen hardleaved forests
2.20.5.	Zagross	evergreen hardleaved forests
2.21.5.	Himalayan-South Chinese	evergreen hardleaved forests
2.22.5.	Nan-shan-ling	evergreen hardleaved forests
2.23.5.	Japanese-South Korean	evergreen hardleaved forests
2.24.6.	Pannonian	steppe
2.25.6.	Anatolian	steppe
2.26.6.	East European	steppe
2.27.6.	Kazakhstan	steppe
2.28.6.	Mongolian	steppe
2.29.6.	East Khingan	steppe
2.30.7	Saharan	desert
2.31.7.	Arabian	desert
2.32.7.	Mesopotamian-Sindian	desert
2.33.7.	Uranian	desert
2.34.7.	Turanian	desert
2.35.7.	Caspian-Bet-pak-dala	desert
2.36.7.	Gobi	desert
2.37.8.	Central Asian	high mountain
2.38.8.	Tibet	high mountain
2.39.8.	Kam	high mountain
2.40.9.	Caspian	lake
2.41.9.	Aral	lake
2.42.9.	Baikal	lake
2.43.9.	Ubsu-Hur	lake

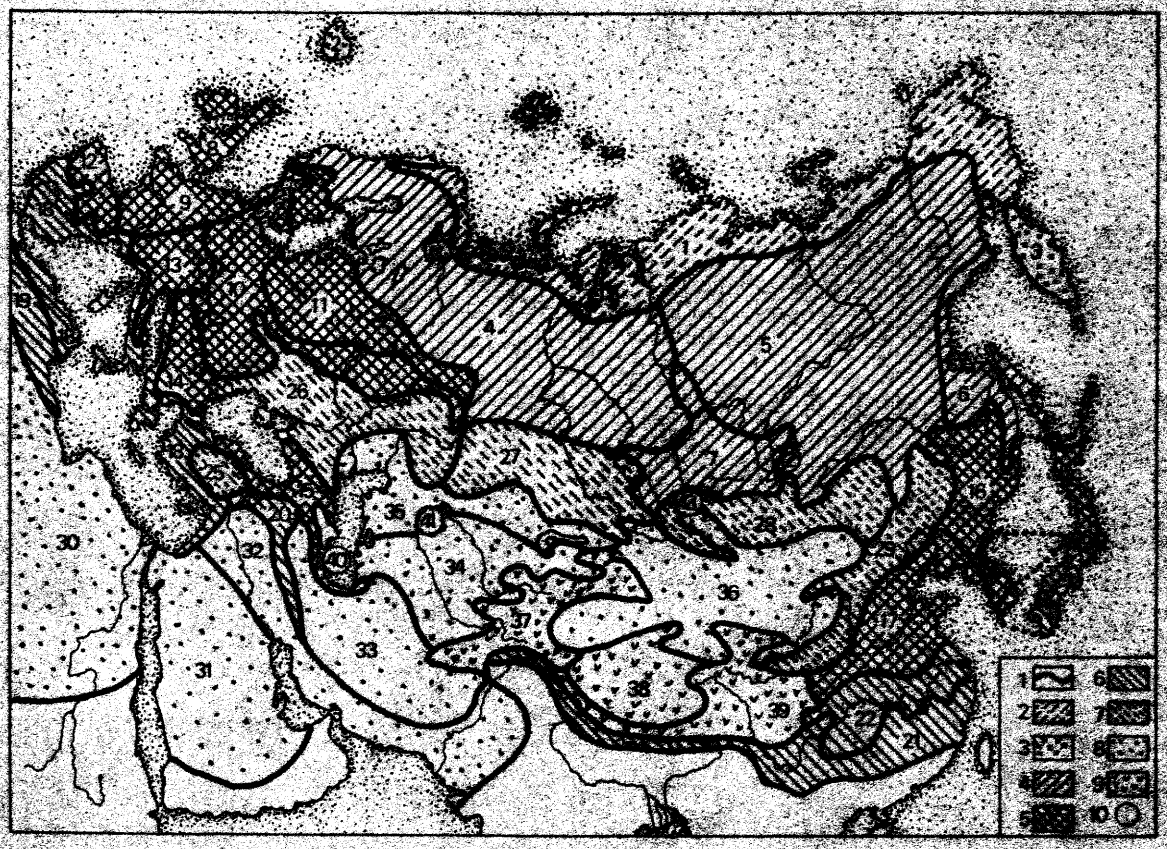

Figure 1.—Biogeographical Regions of the Palearctic: (1) region boundaries; (2) tundra biome; (3) ocean meadow biome; (4) taiga biome; (5) broad-leaf forest biome, green in summer; (6) evergreen, hard-leaf biome; (7) steppe biome; (8) desert biome; (9) alpine biome; (10) lake biome. Names of regions (Provinces) correspond to the numbers on the figure; vide, table 1.

For the Palearctic, M. Udvardy singles out 44 biogeographical provinces which relate to the following 11 types of biomes[2]: (2) subtropical and temperate rain forests; (3) temperate coniferous forests; (5) broadleaved temperate forests and subpolar deciduous thickets; (6) evergreen sclerophyllic forests and shrubs; (7) hot deserts and semi-deserts; (8) deserts and semi-deserts with a cold winter (continental); (9) tundras and arctic deserts; (11) temperate grasslands; (12) mixed ecosystems of mountains and highlands with a range of altitudinal belts; (13) mixed insular ecosystems; (14) lake ecosystems.

In our chart, the Palearctic is divided into 43 provinces which belong to nine types of biomes. The distinction from M. Udvardy's chart is in a somewhat different interpretation of the types of biomes and classification of specific provinces with these types

[2] The name of the type of biome is preceded by its code number.

(table 2). Five types of biomes are practically identical. In our and M. Udvardy's maps (our No. 1 is No. 9 in M. Udvardy's; No. 3 - No. 3; No. 4 - No. 5; No. 6 - No. 11; No. 9 - No. 14), and in a number of other cases the difference is merely in names which we tried to render more laconic.

Table 2--Types of biomes and number of their biogeographical provinces in the Palearctic

Number	Type of biome	No. of provinces	Province
1	Tundra	1	1
2	Ocean coastal meadow	2	2-3
3	Taiga	4	4-7
4	Deciduous broad-leaved forest	10	8-17
5	Evergreen hard-leaved forest	6	18-23
6	Steppe	6	24-29
7	Desert	7	30-36
8	Highlands	3	37-39
9	Lakes	4	40-43

We agree with E. M. Lavrenko (1950) that it is expedient to single out the ocean coastal meadow biome (No. 2). It is also necessary to single out the vast highland biome which should include the high mountains of Middle and Central Asia, Tibet, Kam and, possibly, the alpine belt of some other mountains. The flora and fauna, vegetation cover and the animal life, of this type of a biome has, by both its present day composition and history, very little in common with the desert biomes although most authors place it with Central Asian highlands. At the same time, there are no grounds, at least in Africa and Asia, for breaking the desert biome into two types (warm deserts and cold ones). In our view, placing Iranian deserts in the polar deserts and tundra biome (2.24.9.; 2.25.9.; and 2.26.9.) and forest-tundra with Atlass, Pontian and Mongolo-Manchurian steppes (2.27.11.; 2.28.11.; 2.29.11; 2.30.11.), as suggested by M. Udvardy, is also invalid. It is hardly expedient to pool a large group of mountain provinces (there are nine of them in M. Udvardy's chart, which differ radically in vertical zonality) into one type of a biome: "mixed mountain systems with complex zonality". Smaller distinctions between our suggestions and the views of M. Udvardy are apparent in table 1 and figure 1.

It should be noted that the Dasmann-Udvardy classification does not take into consideration one essential factor: the increase in floristic-faunistic differences from poles to the equator. Thus, many species have circumpolar ranges in the "tundra and polar desert" biome in contrast, the humid tropical forest biome presents such sharp floristic and faunistic distinctions that, in many cases, families and even orders prove to be endemic for different provinces

of a biome of one and the same type. Considering this, we are listing the Palearctic biomes from north to south while the provinces belonging to one and the same type of a biome - from west to east.

We have undertaken an effort to describe the extent of anthropogenic transformation of biogeographical provinces of the Palearctic (table 3, fig. 2).

Table 3--Anthropogenic transformation of palearctic biogeographical provinces (regions)

Degree of anthropogenic transformation	Number of region	
	Considerable portions affected	Affected in spots
Practically not affected	1, 30, 31, 36, 37, 38 39	6, 7
Affected:		
Weakly	3, 5, 6, 7, 28, 34, 35	1, 32
Moderately	4, 15, 16, 29, 33	3, 5, 13, 27, 30 31, 37, 39
Greatly	2, 11, 12, 14, 19, 20, 21, 22, 25	4, 10, 35
Transformed:	8, 9, 10, 13, 17, 18 23, 24, 26, 27, 32	14, 15, 21, 22, 29, 33, 34

The completely and strongly transformed provinces include 8 out of 10 provinces of the biome of deciduous broadleaved forests (Nos. 8-14 and No. 17), all 6 provinces of the biome of hard-leaved evergreen forests (Nos. 18-23), and 4 of the steppe biome provinces (Nos. 24-27). Practically no primary biocenosis survived on the territory of these provinces over any or most of their area. The prevailing landscapes (ploughland, industrial objects, communities, etc.) are of anthropogenic character having no natural analogues. The so-called "natural biocenoses": forest tracts and patches of unforested "virgin land" (marshes, meadows, steppes), are usually situated in areas which are unfit for economic use and have completely lost their original appearance. In these cases, only an attempt can be made on small reference territories to restore semblance of the original, once-dominant communities - sort of "nature museums". The sooner this effort is undertaken the greater the chance of its success.

The practically untransformed or weakly transformed provinces include one in the tundra biome (No. 1), one of two provinces in the ocean coastal meadow biome (No. 3), three out of four provinces in the taiga biome (Nos. 5-7), one out of six in the steppe biome (No. 28),

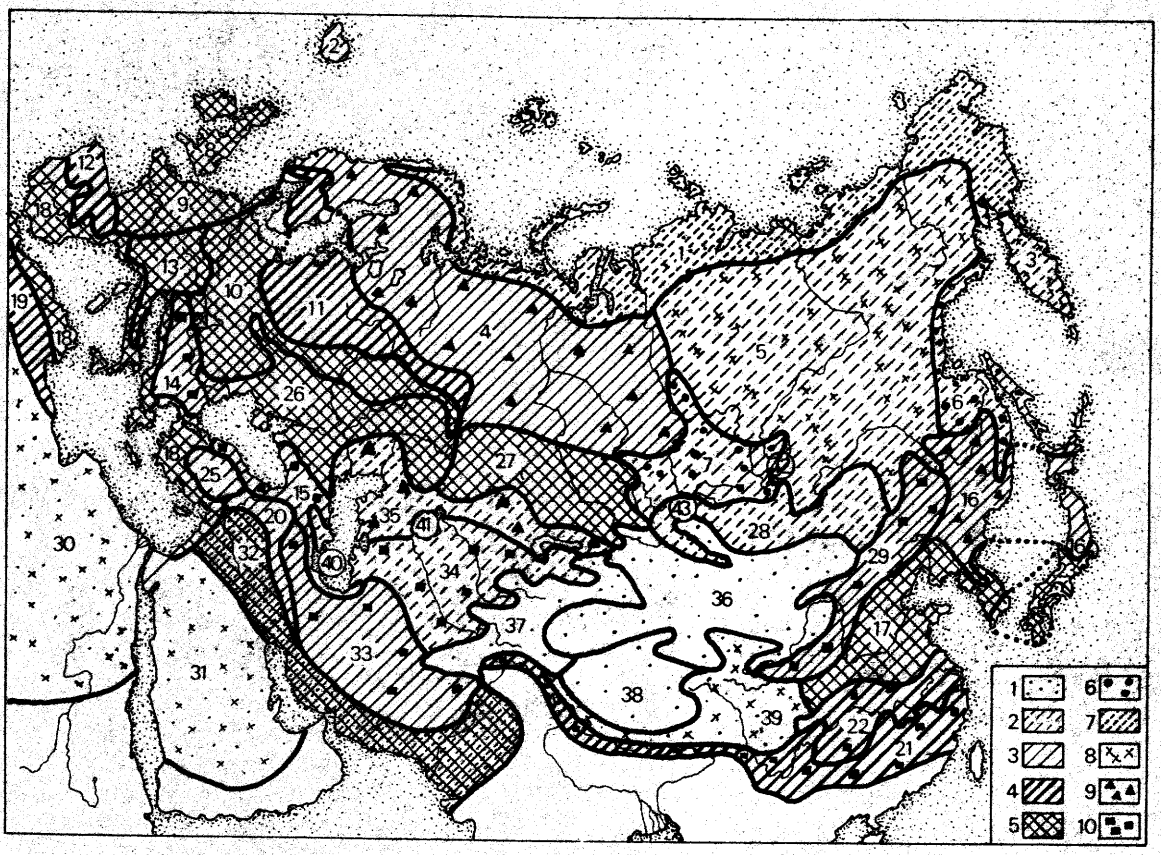

Figure 2.—Degree of anthropogenic transformation of biogeographical provinces (regions) of the Palearctic: 1-5 considerable portion of the territory affected, 6-10 affected in spots. 1 and 6 are practically not affected, 2 and 4 are weakly affected, 3 and 8 are moderately affected, 4 and 9 are greatly affected, and 5 and 10 are transformed.

five out of seven in the desert biome (Nos. 30-31 and 34-36) and all three provinces of the highland biome (Nos. 37-39). The present tasks of nature conservation within these provinces seem quite simple: delimitation of typical and sufficiently large reserve territories. It should be taken into consideration that until recently it was precisely these biomes that were deemed unsuitable or poorly suited for permanent human habitation, while they are presently being intensively developed for economic reasons. The ecosystems of these biomes are easily destroyed. Their original aspect can be restored with great difficulty and only very slowly.

Only five provinces of the Palearctic, belonging to four types of biomes, can be classed as moderately transformed (table 3). The provinces include a considerable number of sections which are weakly damaged by man's activity.

It is necessary to mention some general principles of nature conservation. Until recently, attention was centered on the protection of unique objects of nature occupying small-size territories

(relict communities, caves, picturesque areas, etc.). Today there is a special preoccupation with the necessity of conserving more typical, prevailing, and recently widespread communities which have continued from the first to undergo anthropogenic transformation. Surprising as it may seem, some of these once-dominant associations of biomes of evergreen hardleaved forests, steppes, and deciduous forest have not survived, and the possiblity of recreating them is highly doubtful. It is absolutely necessary to attract public attention to the need of conserving these natural associations which served as the cradle of civilization.

Every biome and the biogeographical provinces on its territory are characterized by a combination of communities and not just the prevailing ones. To use the term of V. B. Sochava (1975), we are dealing not with biocenochores but with biocenomeres, i.e., not with categories of different ranks encompassing typological units of different level but with categories including combinations of territorially-conjugated associations ("facias"[3/], "urochischas"[3/], "localities"[3/] and landscapes) of increasing area and complexity.

It is important from the conservation viewpoint to recognize that any province incorporates (as it was mentioned earlier) zonal, intra-zonal and extra-zonal associations and some species of plants and animals which are confined to only one of the groups or conditions. Therefore, a protected territory should be delimited so as to encompass a variety of types of communities confined to differing morphological parts of the landscape, differing elements of topography, soils of various mechanical and chemical composition, etc.

In addition, different approaches should be used to protect communities and to protect plant and animal species. These distinctions are based on the following:

The protection of biocenosis is a much more difficult task than the protection of individual species since a species cannot be destroyed without destroying (directly or by changing the environment) the prevailing part of its representatives. Furthermore, species can be preserved at botanical and zoological gardens or in the reserves where they are specifically protected. On the other hand, even a moderate human action upon a biocenosis (mowing, grazing of domestic animals, destruction of the moss cover in forests, etc.), or an excessive increase in the number of some herbivorous wild animals, like that of the moose in some parts of the forest zone of the U.S.S.R., might lead to the replacement of an association. It is true that natural communities have the ability of self-restoration but this ability is not infinite. As soon as a community passes its tolerance limit, changes become irreversible and different lasting derivatives or artifical communities develop on the territory.

Complete conservation of all protected objects even on small territories with numerous centers of endemism involves either the establishment of a huge number of small reserves or carrying out nature conservation measures on areas of such vastness excluding them from economic use that it becomes impracticable.

3/ Russian terms having no English versions.

Therefore, the biota and biomes can be protected only by applying a variety of measures. Besides the establishment of exclusive reserves including biosphere reserves or national parks (with controlled access for tourists and vacationers), there should be protected territories of other types: fixed-term preserves, individually protected nature monuments, etc. Maintenance of certain species in artificial conditions--zoos, botanical gardens, etc.--is also necessary. Certain objects should also be protected on territories which are used by man and which, under any circumstances, will comprise the greater part of land surface.

A first approximation of the availability of reserves in biogeographical provinces of the Palearctic, is seen on table 4 (fig. 3). It is noteworthy that there are no reserves in the practically untransformed or weakly transformed provinces (table 3). For instance, there are no reserves in the sole province of the tundra biome, two provinces (Nos. 5 and 6) of the taiga biome, one province (No. 28) of the steppe biome, five provinces (Nos. 30-33 and 35) of the desert biome, and two provinces (Nos. 38 and 39) of the highland biome. Similarly, there are no protected territories in the provinces of the oldest farm crops (Nos. 17, and 20-22). As for the first group of provinces, the possiblity of establishing reserves is not altogether lost and they should be established there in the next decade. Particular attention is drawn to the Mongolian province (No. 28)--it is the only province of the steppe biome of the Palearctic which is preserved in the natural state. The establishment of a reserve on its territory is an urgent matter. As for the provinces of the oldest agricultural crops, the very possibility of establishing reserves of adequate size and, specifically, of restoring the peculiar primary conditions of these biocenoses are highly doubtful.

The information offered will doubtless be amended and supplemented; we believe, however, that it generally agrees with reality. It will be interesting to ascertain the extent of man-caused damage and the rate of availability of reserves in the Nearctic biomes and biotic provinces which are similar to the corresponding biomes and biotic provinces of the Palearctic.

Table 4.--Territories of the biogeographical Palearctic regions provided with Zapovedniks

Presence of Zapovedniks	No. of biogeographical region
None	1, 5, 6, 7, 17, 20[2], 21, 22, 28, 29, 29, 30, 31, 32, 33[2], 35, 38, 39
Present:	
Few	3, 24, 25, 27, 34, 36
Sufficient	2, 4, 7, 8, 9*, 10, 11, 12, 13, 14, 15*, 16, 18*, 19, 23, 26, 37

* M spots

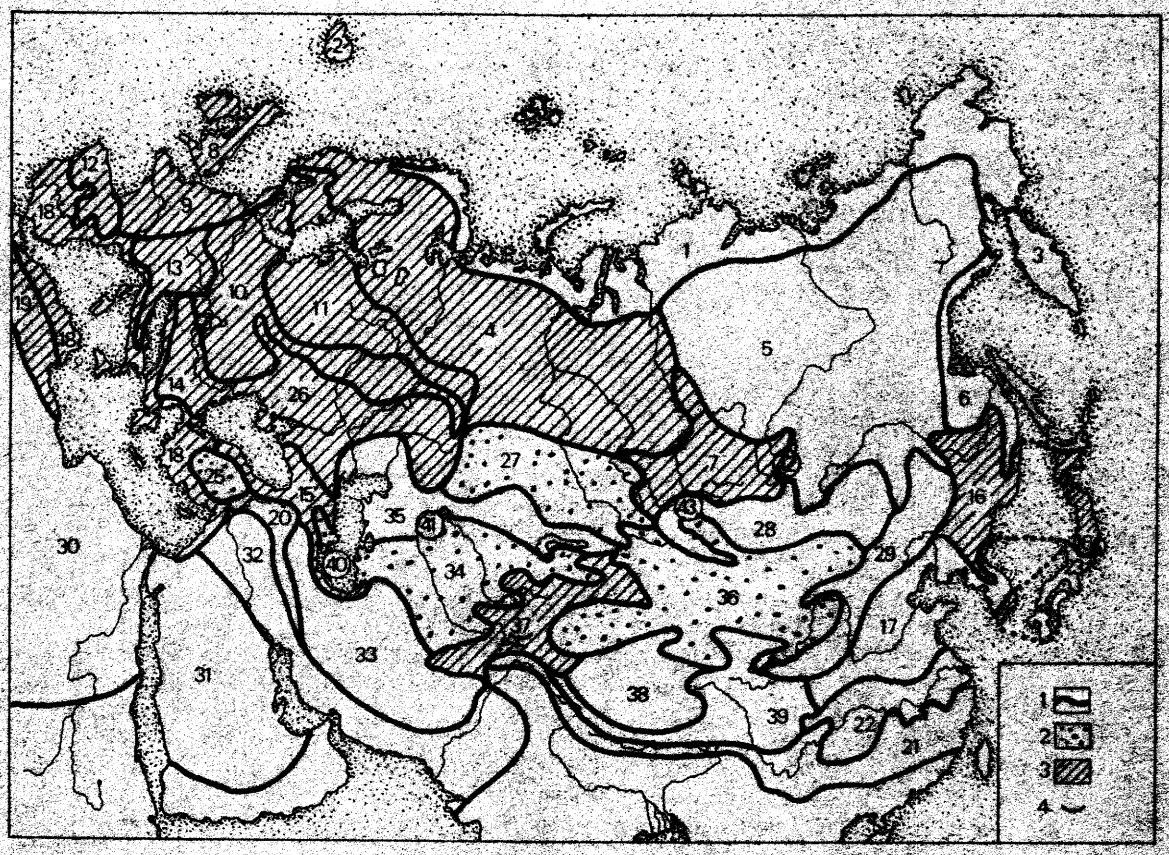

Figure 3.—Biogeographical Regions of the Palearctic provided with Zapovedniks: (1) boundaries of regions, (2) none, (3) few, (4) sufficient, (5) sufficient in certain spots.

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The Influence of Pollution on the Biosphere and Its Monitoring Based on Biosphere Reserves

by

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The increasing intensity of anthropogenic influences upon the environment urges the establishment of such priority tasks as the development of an optimal system for observation and appraisal of biosphere conditions and trends, as well as the elaboration of measures based on the data supplied by that system for effective regulation of the quality of the environment and for reducing harmful anthropogenic influence on the biosphere. Hence, the theory of retrieving and processing information on the state of the biosphere, pollution levels, and the reaction of the biota (individuals, populations, and ecosystems) to environmental factors becomes important.

To design an optimal program of regulating the quality of environment it is imperative to have precise answers to the following questions:

1. What is the background environmental condition?

2. What is the observed state and the observed level of anthropogenic influence on the biota?

3. What is the critical level of anthropogenic influence on the biota?

4. What is the permissible level of anthropogenic influence on the biota?

The answer to the first, and largely to the second question should be provided by a subsystem of national, and partially global monitoring of biosphere reserves.

Biosphere reserves should be the most essential component of the entire system of observation, evaluation, and forecasting of the state of the environment; since, we believe that in the identification of permissible levels of anthropogenic influence on the biosphere, it is necessary to use as a reference base the parts of the biosphere free from local influences. It is necessary to take into consideration all environmental components, e.g., an individual organism, a population, an association, an ecological system, and, finally, the biosphere as a whole.

To determine the maximum permissible burden, it is essential to formulate what quality of environment we consider as high (adequate). We believe that for a definite ecosystem, the high quality of environment should incorporate: (a) the possibility of stable existence and development of the given and historically man-made or transformed ecological system in a given place (district); and (b) the historical or temporary absence of unfavorable consequences for any population (first and foremost being human) in a given place. In this case, we may speak about the quality of environment for the given population.

There are identifiable biological (ecological) criteria which characterize a high quality of environment: high biological productivity, optimal species composition and ratio, the biomass of populations at different trophic levels, etc.

In the broadest sense, we may interpret as the permissible anthropogenic load (which is produced by individual homogeneous and heterogeneous influences) which does not alter the quality of environment or which alters it within permissible limits, i.e., does not induce destruction of existing ecological systems nor the emergence of unfavorable consequences in the most important populations (first and foremost being human populations).

Let us introduce a certain function of the state of the ecosystem or of another element of the biosphere (characterizing, for instance, the biomass volume, productivity, the rate of metabolism and energy in a system, or the combination of these and other similar factors). In $\zeta(\vec{R},t)$ (changes in space and time), or the generalized function for the region, we have

$$\zeta^*(t) = \int_{\vec{R}} \zeta(\vec{R},t)\, d\vec{R} \qquad (1)$$

This function can represent the entire ecosystem or for any level or any population, and then be considered with the limits permissible for it.

Let us introduce the function of anthropogenic influence capable of altering the state of the given ecosystem $H(\vec{R},t)$ or

$$\varkappa^*(t) = \int_{\vec{R}} \varkappa(\vec{R},t)\, d\vec{R}\,. \qquad (2)$$

Then, the function

$$Z_n^*(t) = Z^*(t)\,\alpha^*(t) \qquad (3)$$

describes the altered state of the biosphere elements under the influence of the given anthropogenic factor.

To establish a monitoring system, it is necessary to select the site of a station in a way that satisfies the following conditions:

$$\frac{\int_R Z_n(\vec{R},t)\,d\vec{R}}{\int_R Z_n^{max}(\vec{R},t)\,d\vec{R}} \geq 0.7 - 0.8 \qquad (4)$$

where Z_n^{max} is the function of the condition obtained by measuring with the help of the given system. Condition (4) is therefore a criterion for selecting and organizing a sufficient system of monitoring (e.g., a network of stations). In some cases, a considerable number of stations shall be established, in others even a small number will produce highly representative data. For instance, to arrange a monitoring system of influence upon a human population a large number of stations will be needed in towns and industrial districts (where the intensities of factors of influence are high), and a smaller number of stations in rural districts.

A smaller number of stations will be required to observe the state of vegetation, since only a small share of it grows in towns, whereas the bulk grows in zones of intermediate (regional level) or weak (background level) influence. It will be necessary to have specialized observations made in farming zones where vegetation is subjected to pesticide influence. A specific network will be also required to observe the pollution of the ocean and its impact on the biota.

A very small number of stations can give sufficient information on the state of the flora and fauna in the conservation areas for animal and plant genetic pools (reserves). The creation of a comparatively small number of biosphere reserves (stations) capable of a wide range of measurements and studies will be of a considerable value in their own right.

Thus, a combined theoretical and operative program of activity at biosphere reserves should be decisive in designing an optimal strategy for man in the way he relates to his environment.

Another important task of biosphere reserves, along with the evaluation of biosphere conditions and their tendency to change, is the study of the function and structure of ecosystems, in order to work out scientifically valid indicators of the state of ecosystems. Indeed, precisely this set of studies (known as biological monitoring) is the least theoretically developed and, therefore, the least applicable in practice. At the same time, one must develop an optimal strategy of controlling the quality of the natural environment and, in particular, an optimal system of evaluation and forecasting the state of the biosphere. During a time of rapid technical progress, one has to know not merely the influence of pollutants and other factors on man's health but also on other organisms and ecological systems. One must know not merely the effect of one or another pollutant but the effect of the entire range of chemical, physical, and biological factors which influence the biosphere and all its elements concurrently. One must understand not only the influence of environmental factors upon the structure and functioning of ecosystems but the dynamics of these indicators as related to the dynamics of the changing chemical and physical indices of the state of environment (for instance, global or local climatic changes).

Baseline observations are in their infancy. Their main goal is information on the initial state of the biosphere, its present level of pollution, the ways and rate of spread of pollutants over great distances, and directions in the changes of environmental quality. Observations should also make it possible to distinguish the unfavorable changes caused by human activity against a background of natural processes. The resulting information is necessary to understand the basic physicial, chemical, and biological processes; to broaden our knowledge of the influences upon ecological systems and the biosphere as a whole; and to determine, in the final analysis, the present directions of environmental changes, to work out forecasts for the biosphere and recommendations for the optimal control of environments, including the global environment.

The aim of baseline observations may be fully achieved only if this work is conducted on a global scale. Thus, any national system of baseline observation is a component of a global system. In this respect the network of baseline observation which is being developed in the U.S.S.R. provides for concurrent participation in a number of large international projects, like the Global Environmental Monitoring System (regional and base stations), United Nations Environmental Program (monitoring of atmospheric pollution by the World Meteorological Organization), 8 and 14 projects of the United Nations Educational, Scientific and Cultural Organization, "Man and Biosphere" program, biosphere reserves, etc. At the present time, the main concepts of background monitoring have been developed and are included in appropriate international documents drafted by the above-mentioned international organizations.

It is intended to establish in the U.S.S.R., for baseline monitoring, a series of terrestrial biosphere reserves and at least one marine biosphere reserve in the central Atlantic. When selecting the sites for the biosphere reserves, the extent of

anthropogenic influence in a given area and the representative character of the physiographical zones will be taken into consideration. At least one biosphere reserve will be situated in tundra, desert, taiga, and forest-steppe zones. This is where the maximum program for background monitoring will be implemented and will include ecological and biological studies.

The program of baseline monitoring provides for the following observations: in atmospheric air, sulphur dioxide, carbon monoxide and dioxide, nitric oxides, ozone, reaction-capable hydrocarbons, aerosols, contents of lead, mercury, arsenic, and cadmium, and, in keeping with the World Meteorological Organization (WMO) program, sodium, chlorine, and sulphates; in atmospheric fallout and precipitation, DDT and other organochlorides like polychlorbiphenyls, lead, mercury, arsenic, cadmium, and, additionally, in keeping with the WMO program, sulphates, chlorides, etc.; in natural waters, DDT and polychlorbiphenyls, lead, mercury, arsenic, cadmium, and additionally, in marine waters, oil products; in soils and in the biota, DDT and polychlorbiphenyls, lead, mercury, arsenic, and cadmium.

Observations will include a standard monitoring program for accompanying factors (hydrometeorological and climatological observations) necessary for decoding these observations on the level of the contamination. These independent indicators of environmental quality will be conducted at regional and baseline stations, including the biosphere reserves.

It seems that an important condition for background monitoring is to secure not only integrated observation, but also information of the circulation of the above-mentioned substances. This aspect places great demands on the organization of observations, taking into account the intralandscape migrational relationships. The idea to establish a bank of representative specimens for future studies with chronologically reliable material is interesting, though thus far, difficult to implement.

It should be noted that the above-mentioned list of substances for baseline monitoring is not fixed once and for all and may be revised as our knowledge on the global distribution of discharged substances increases. To have the scientific background to do this, it is necessary to have studies at some of the regional and baseline stations. The first toxicant is most likely benz-a-pyrene, which is both interesting itself and as an indicator of other hydrocarbons of anthropogenic origin.

Thus, the organization of biosphere reserves, and the elaboration of the theoretical and operative working programs in them should be an essential stage towards regulating the quality of environment.

Anthropogenic Transformations of Natural Ecosystems and Their Study at Biosphere Station-Reserves

by

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1. The section about the tasks of station-reserves in the general report on the system of biosphere reserves in the U.S.S.R., compiled by Izrael et al. (1975) indicates that one of their basic tasks is the "continued, regular, and focused studies of various ecosystems to develop scientifically valid parameters of controlling the state of environment and their importance for man's well-being."

2. We emphasize in the above paper that the main attention should be given to biotic components of ecosystems, since they are primarily the objects of anthropogenic influence and are the most sensitive indicators of changes in environment. At the same time, the study of biotic components should be conducted first of all on the so-called ecosystem (biocenotic) level and supplemented by studies on the physiological and genetic levels of the species. The main attention on the ecosystem level should be given to: (a) the identification of the biota's composition and its changes under anthropogenic influences; (b) the observation on the functional vitality of producers, consumer and reducers in different ecosystems; and (c) the identification of the levels of primary and secondary productivity, etc. The main attention on the species' level, most likely, should be given to the population dynamics of indicator (key) species of plants and animals; on the physiological level, to the photosynthesis, respiration, growth, and reproduction of the biota; on the genetic level, to mutagenesis, teratogenesis, etc.

It is indispensable that the study of biotic components should be related to environmental factors and, primarily, the radiation balance on the territory, its thermal and hydro regimens, etc. It is also necessary to insure that such a system of observations would make possible the transformation of the primary above-mentioned parameters of environments into appropriate parameters for the studied ecosystems (for instance, microclimate) and vice versa.

Finally, alongside the biotic and abiotic components, the biosphere stations (reserves) should observe indicators of different developments and processes in ecosystems which are the result of environment-biota interaction. Priority should be given to observations on soil dynamics (the thermal and hydro regimen,

gas composition, and changes in reactions). This set of observations should include biogeochemical studies of the circulation of the most important nutritive and biogenic substances and their anthropogenic transformations.

3. In general, the range of consequences and products of anthropogenic influences on natural ecosystems should comprise a particularly important area of observation at biosphere station-reserves in their "buffer" or native zones. At the same time, the observed objects should make up a consistent series of ecosystems. The ecosystems should range from primary links--natural ecosystems which are subject to relatively weak anthropogenic influences (like exploited forests; pasture and mowing lands, plowlands where conventional farming methods are used; recreational territories; etc.)--to wastelands, on the one hand, and the natural-cultivated ecosystems, on the other hand, which have experienced specificially profound anthropogenic transformations (for instance, forest plantations, parks, ameliorated plowlands, artificial meadows, etc.). It should be repeated that tracts or plots of preserved natural ecosystems, typical for the given natural region and strictly protected under reserve status, should be used as a reference base for changes that have occurred or are occurring.

4. As was indicated earlier, the main task of these observations and studies should be the development of scientifically substantiated parameters for the broadening of observations and control over the state of environment (monitoring). It is known that the most widespread indicators of this monitoring are the toxic indicators of air and water pollution and also contamination of soil; i.e., the so-called indicators of the maximum allowable concentration (MAC) of certain substances discharged into the environment with industrial and domestic waste, pesticides, etc. It is known that such indicators or quotas are, and should be, related to man. It is clear that their list may be and should be extended, however, either on the strength of their toxicity or because of other forms of influence they have on many species of plants and animals. This is also necessary because many such substances enter the trophic chain in the processes of agricultural production, livestock breeding, fishing, etc.

When the task is formulated in this way, however, it becomes necessary to comprehensively study the range of trophic and other relationships in natural and natural-cultivated ecosystems, i.e., include their study in ecological programs at biosphere station-reserves which are being considered.

5. It is likewise necessary to consider that the determination of the environment's natural ability to autoclean (ACA) is essential for the proper ecological evaluation of indicators or quotas of the MAC of pollutants. This ability is also predetermined by the existence of definite trophic and other (biogeochemical) relationships among the components of natural ecosystems and also of a definite volume and intensity of natural biological circulation of substances. Therefore, when we introduce into the parameters of ecological observations at biosphere station-reserves the indicators of ACA,

we cannot only state the "excess load" of pollutants and other substances on natural ecosystems but also determine (forecast) the maximum allowable load (MAL) on one or another ecosystem (including the natural-cultivated) of different domestic and industrial waste, with which the given ecosystem can more or less cope thanks to its ACA. It is apparent that the indicators of ACA and MAC should be studied and determined by comprehensive investigation of trophic relations and intensity of the biochemical circulation of substances in the main types of natural ecosystems in separate river basins and different types of reservoirs.

6. The most important results of ecological studies at biosphere station-reserves should be the identification of the levels of efficiency of utilization of natural resources of the biosphere and the changes in natural and cultivated productivity of ecosystems under the influence of various technical measures. One of the most important properties of natural ecosystems is their biological productivity (BP). Therefore, we believe that the ecological studies at biosphere reserves should include indicators of BP both for natural and manmade "natural-technical" ecosystems (agricultural systems, forest plantations, etc.). The comparison of these indicators will make it possible to determine the levels of effective utilization of a number of natural resources (climatic, terrestrial, aquatic, biologic, etc.) expressed in accurate quantitative parameters. This will make it possible to go over from conventional empirical and statistical norms of different technical measure (agriculture, forestry, amelioration, etc.) to scientifically substantiated and predictable utilization efficiency factor (UEF) for various types of natural resources.

7. I believe, however, that the determination of the intensity and the character of anthropogenic influence upon natural ecosystems should not be confined to the above-mentioned factors (MAC, MAL, ACA, and UEF). Most important at present is quantitative "demonstration" of the widespread notion of the existence of a natural ecological equilibrium whose disruption leads, as they say, to the "devastation" of nature. Essentially, these expressions denote a radical destruction of natural ecosystems. This destruction is due to cardinal changes in the natural flows of energy and matter and the disruption of the dynamics and balances formed through ages of evolution. There emerge and develop irreversible phenomena which exceed the limits of "stability" (specifically the MAL and ACA) and which lead to the dislocation of the entire ecosystem. The instances of this type are plentiful. We can mention the accelerated processes of the soil erosion which take place when the natural water balance is disrupted or in case of deforestation or excessive plowing of water drainage territory; and eutrophication ("blooming") of water reservoirs, which arises when surplus volumes of so-called nutritive substances flow in from the surrounding water discharge areas.

8. A question arises, however, have we at the present time a sufficiently developed scientific approach and the techniques for studying the processes of similar disruption of "ecological equilibrium" in natural ecosystems and their radical "devastation" owing to

anthropogenic influences? This is followed by another even more specific question: Are we in a position to use at biosphere station-reserves a method of identifying the intensity of anthropogenic influence on natural ecosystems taken as a whole? I can give a positive answer to these questions with a great deal of certainty. I have in mind those suggestions related to the techniques of studying the internal circulation of substances in natural ecosystems and the relevant dislocations which were suggested by us (I. P. Gerasimov, Y. A. Isakov, and D. V. Panfilov) in the form of systems of so-called structural-functional indicators.

9. At the moment, out of a system of such indicators, I shall single out three, for the sake of simplicity. These indicators are: (a) the balance of biological production (the relation of primary and secondary BP); (b) the rate of formation of biological production (the relation of annual primary and secondary biological production to the overall biomass); and (c) the intensity of the circulation of substances (in i.e., the disportion of mobile substances incorporated into the biological circulation reserve in relation to their general stock.

I shall not go deeper into the explanation of these indicators. It should be mentioned only that they are based on the characteristics of the processes of creation, utilization, destruction, and residual accumulation of biological production (primary, secondary) in ecosystems of different categories and the circulation of substances involved in the biological circulations. Thus, the above-mentioned functional-structural indicators describe the most general and essential phenomena, characterisitic of natural ecosystems and which determine its internal matter-energy dynamics.

This can be explained by the known example of the so-called trophic matter-energy pyramid (the relationship of producers, consumers, reducers and their production in natural ecosystems). This figure in itself can symbolize an ecologically balanced natural ecosystem or be its graphic model. Different types of functional structure of climax natural ecosystems differ by size and some other peculiarities of their graphic representation; nevertheless, all of them belong to this type of equilibrium model. This is easily seen if one uses or inserts concrete quantitative characteristics for different types of climax ecosystems (for instance, forest, steppe, desert, etc.) into the basic graphic scheme of the trophic (matter-energy) "pyramid."

The graphic models built in keeping with the functional-structural indicators have an absolutely different effect (not to speak of the sizes) both for succession ecosystems and for ecosystems altered under anthropogenic influences. The equilibrium of the main elements of functional structures is disrupted (to varying degrees) in all of them. For instance, the level of primary biological production compared with the secondary production is disproportionately large, the stock of residual production is disproportionally depleted, or secondary production is catastrophically small. This shows clearly the disrupted "equilibrium" of such systems and it is expressed in different

deformations of the appropriate graphic models. It is likewise clear that such deformations might be readily described in a mathematical form.

To elucidate these suggestions, we present a basic chart of anthropogenic disruptions of natural ecosystems due to forestry, agriculture, and animal husbandry (fig. 1).

In conditions of forestry (without aforestation) we extract from natural forest ecosystems definite volumes of residual biological production (wood). In this way we disrupt (deplete), first of all, the volume (intensity) of the natural circulation of substances. This leads to the weakening of biogenic circulations which maintain the natural level of primary and secondary biological productivity. Consequently, its reduction results in disruption of the natural balance and rate of formation. Subject to the extent of this extraction, the disruption of the ecological balance in a natural forest ecosystem may vary, leading even to its complete destruction.

Under the conditions of farming, we first liquidate all the surface residual biological production in a natural ecosystem and then go on to remove annually a considerable part of the primary biological production. The first action violates the intensity (volume) of the circulation of the biogenic substances which, however, is amply compensated by the introduction of nutrients (manure, fertilizers, etc.). This insures an intensification of the biogenic circulation of substances which is indispensable for an increase in the primary biological productivity (harvest). Considerable annual withdrawals of this production, however, cause a reduction in secondary biological productivity and the weakening (liquidation) of the return of substances to biogenic circulation. As the result of all these alterations, we see a disruption both of the natural balance of biological production and the rate (volume) of the formation of its residual part. Subject to the volume of the liquidated surface residual biological production, the size of annual withdrawal of primary production, and the artificial increase in biogenic substances, the extent of the disruption of ecological equilibrium in a natural ecosystem used for farming needs might vary. The appropriate characteristics of these disruptions (including the above-mentioned structural-functional indicators) might be fruitfully applied to determine the utilization efficiency factors of some land resources (soil types).

Under circumstances of grazing and livestock breeding, we withdraw from natural ecosystems certain volumes of secondary biological production. This weakens the return of biogenic substances into circulation. At the same time, we seek to increase secondary biological production. This calls for an invigoration of the biogenic circulation of substances and definite links (at the expense of others) and results in a reduction of the primary (pasture degression) and residual biological production. All this leads to a disruption of the natural ecological equilibrium in the ecosystems which are used

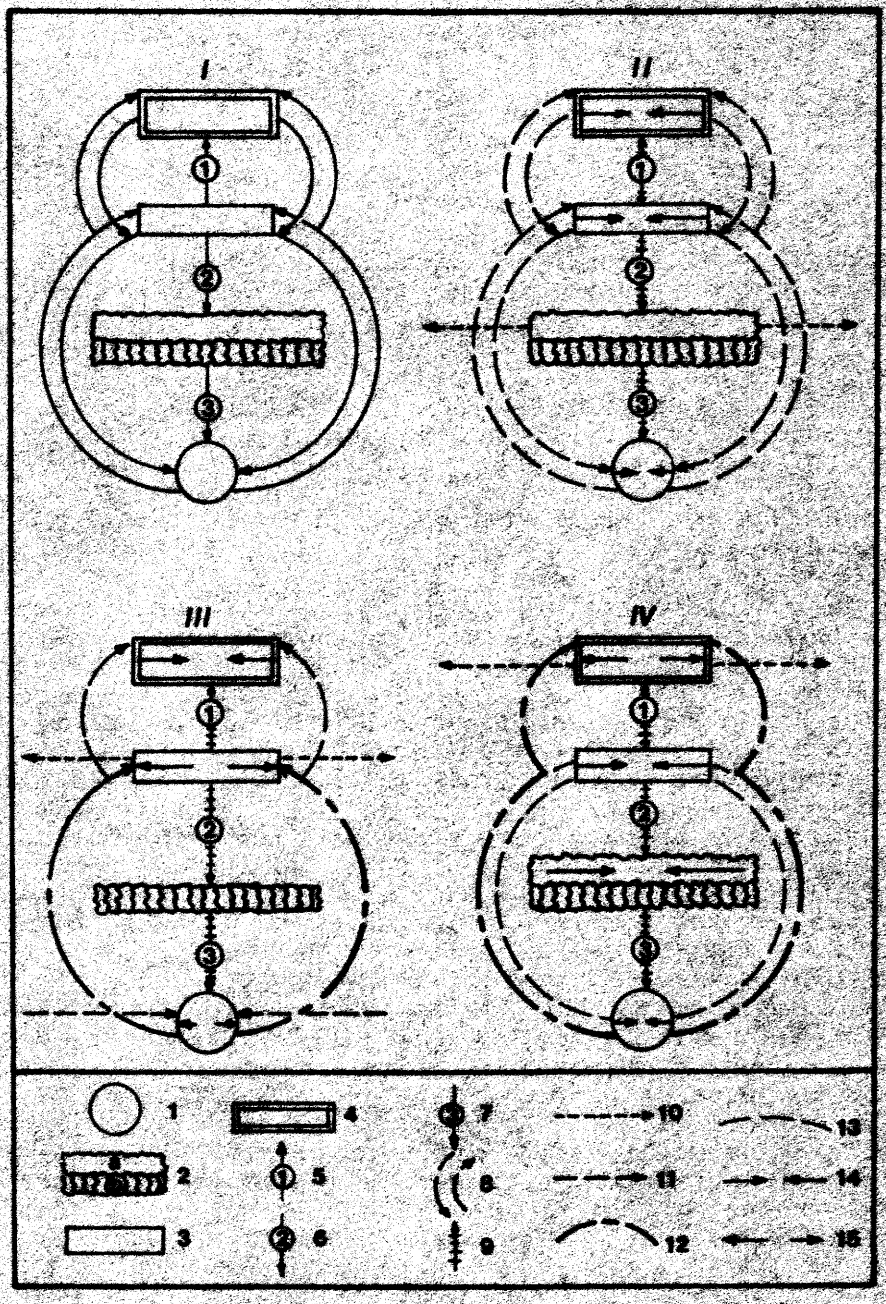

Figure 1.— Principal types of disturbance of natural, balanced ecosystems: 1-Mobile biogens, 2-general biological mass and reserve in mass (a) surface, (b) subsurface, 3-primary biological production/annual, 4-secondary biological production/annual, 5-balanced biological production, 6-rate of formation of biological production, 7-intensity of substance circulation, 8-biogenic circulation of substances, 9-disturbance, 10-removal, 11-introduction, 12-intensification, 13-weakening, 14-diminution, 15-increase. Principal anthropogenic disturbances of a natural balanced ecosystem: (I) under forestry conditions, (II) without afforestation, (III) in farming, (IV) grazing.

for livestock breeding and is expressed in different structural-functional indicators (including those used in our models).

10. The above-mentioned approach to identifying functional structures of natural ecosystems and their anthropogenic deformations has been presented in a number of publications and in a symposium on biosphere reserves.

There is the possibility, at present, to use this approach on a larger scope with regard to local variants of natural and native-cultivated ecosystems. This is possible for forest-steppe ecosystems, using materials representing many years of observation in the central forest-steppe of the Russian plain (Kursk Experimental Station of the Institute of Geography, U.S.S.R. Academy of Sciences); as for taiga ecosystems, we may use mainly the data accumulated at stationary installations of the Institute of Geography and the Institute of Forest and Timber, U.S.S.R. Academy of Sciences (Baikal area), and of the Institute of Deserts, Academy of Sciences of the Turkmen S.S.R., for desert ecosystems at the Repetek station. I believe that precisely these districts are of specific interest at present since all of them belong to the projected Soviet network of biosphere stations which has been suggested in the general report of Izrael et al. (1975). I trust that we will be in a position to report some results of this type of a study program at the next symposium devoted to biosphere station-reserves.

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Research at U.S.S.R. State Reserves and Their Role in Monitoring Biosphere Changes

by

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State reserves in the U.S.S.R. hold a leading place among territories singled out for the preservation of biotic plant and animal associations within the areas of natural ecosystems and for protecting genetic diversity of species. By their objectives, established regimen, and functions state reserves differ from National Parks, relics of nature, wild animal reservations, and the so-called primitive regions and other administrative forms of protected natural territories in the United States. (In other languages, apparently, there is no true synonym for the term "zapovednik", which adequately and accurately conveys the specifics of this form of protection and study. Rather than attempting to use analogous concepts, it would be better to adopt its transcription.)

The idea of state reserves is to preserve typical areas of the main biogeographical subdivisions of the national territory with their natural diversity of plant cover and the animal population peculiar to these subdivisions. The reserves are completely withdrawn from all forms of tourism, recreation, and economic utilization, including timber-cutting or hay-mowing. The network of reserves represents a system of reference types of zonal and provincial landscapes which are necessary for comparison against the territories which are used for economic purposes and are ecological models for the restoration of natural ecosystems.

The Soviet Union has 130 state reserves, their total area exceeding 9 million hectares. They are located in the Arctic, tundra, taiga, mixed and broadleaved forests, in the forest-steppes, steppes, deserts, in mountain systems and in maritime zones. Most frequently, a single reserve covers an area of 30 000-70 000 hectares; however, there are reserves with an area of 700 000-900 000 hectares; some, located in the densely populated districts, cover less than 5 000 hectares.

Reserves play an important part in preserving and reproducing many species of animals and plants, including those on the verge of extinction. It is evident that under contemporary conditions, the protection of living species, the preservation of our planet's gene-pool, can best be achieved by protecting natural habitat, as in reserve territories. It is precisely in this way that in the U.S.S.R. many examples of plant and animal life have been preserved; examples are the tiger, leopard, snow leopard, musquash, European

bison, flamingo, the lotus, pistachio, yew-tree, etc. Thus, when the Barguzin Reserve at Lake Baikal was established, there were about 20 or 30 sables there in shelters in inaccessible rock streams. At present, sables which spread out from the reserve comprise a large population of commercial significance. There were several pairs of beavers at the Voronezh area before the establishment of the reserve. In the 50 years of the reserve's operation more than 3,000 beavers were taken from it and re-settled in 73 districts of the U.S.S.R. These beavers produced 70,000 offspring. Slightly more than 100 wild reindeer had survived in the Kola peninsula within the Lapland tundra area. At present, there are approximately 20,000 reindeer in the Lapland Reserve. It seems that with present conditions, the protection of living species and the preservation of the gene-fund of our planet can be particularly successful by protecting the places of their habitation, beginning with those within reserve territories.

The network of Soviet Reserves is growing regularly. In the last 10 years alone, 30 reserves were established on an area exceeding 3 million hectares; it is expected in the next 5-10 years to establish another 30 reserves on an area approximating 4 million hectares, mainly in the Arctic, taiga, steppe, desert, and in the mountain systems. As the result of this, reserves will represent all the main biomes and biomic subdivisions of our country.

Soviet Reserves are research establishments with an aggregate staff of more than 1,000 associates and specialists. They conduct studies in keeping with coordinated programs; besides this, there is approximately an equal number of scientists from other organizations and establishments of the country working at these reserves.

Reserves have been of great importance as regional scientific centers for integrated nature research. The examination of the regularities of biological circulation and other natural processes of natural ecosystems are particularly successful on the territory of reserves through the participation of their research staffs. The understanding of these processes makes it possible not only to forecast the results of the anthropogenic transformation of natural ecosystems, but also to find ways of regulating it.

Traditionally, many scientific programs at reserves are devoted to the ecology of individual plant species and animals which were threatened with extinction. Detailed examination of the characteristics of individual species, their habitat pecularities of feeding, breeding, and wintering, has provided a scientific foundation for the elaboration of measures to preserve, restore and wisely utilize the existing stocks of rare animal and plant species. This scientific foundation has been used for the successful preservation, in the U.S.S.R. of 18 species of extremely rare animals, 29 species of rare birds, and of many rare plants. Mention can be made of animals such as the aurochs, cheetah, tiger, leopard, culan, mountain antelope, desman, francoline, flamingo, and eider; as for plants, mention can also be made of the lotus, yew, pistachio, and many others.

The main content of research at reserves is determined by many years of biogeocenological studies. The latter makes in possible to investigate the cycles of intricate natural phenomena which take many years and to follow the changes in the structure of natural complexes. This primary form of biogeocenological observation is referred to as nature's records and is performed in keeping with a strictly defined program, providing for the registration of all conventional and extraordinary phenomena in the reserve. This includes meteorological, microclimatic and hydrological observations, the registration of phenological phenomena, measuring the production of different plant groupings, evaluation of the harvest of plant fruit and seeds, inventory of the number of animals, characterization of conditions for wintering, reproduction and other vital statistics. Nature's records also register the deviations in the state of natural conditions: droughts, severe winters, avalanches, high freshets, downpours, storms, forest fires, epizootics, outbreaks of entomopests, etc. All facts of anthropogenic influence on the reserve's territory are carefully recorded. These include the changes in the hydrological regimen, the entry of synanthropic species, domestic animals, species which became acclimatized in neighboring territories, etc. The consequences of all these events are analyzed, and the restoration of the damaged state of nature is observed. Every year the data are processed for successive publication of nature's record and once in 5 years a consolidated book is compiled. The scientific fund of the reserve also incorporates other materials: photodocuments of landscapes and natural phenomena, maps and diagrams of the distribution of vegetation and reservoirs and other elements of the landscape, the location of bird nests, burrows, bird mating grounds, paths of animals, results of measuring meteorological and hydrological data, of soil-forming processes, the registration of phenological phenomena, animal encounters, and also the collected materials like herbariums, soil or rock monoliths, entomological collections, carcasses of animals, preparations, skulls, etc. Nature's record and the collection of primary scientific data have been collected for quite some time at all reserves in keeping with a uniform scheme; in many reserves the period covered by such data is more than 50 years. These materials, particularly those which cover many years, are of considerable value; and in a number of instances they may serve as the standard reference on natural environment against which we should compare the environmental parameters from areas exploited by man.

Integrated, permanent research programs are based on large-scale maps of topography, soil, water reservoirs, vegetation, forest types, and other physico-geographical conditions, as well as the results of flora and fauna inventories and materials covering the history of the territory which are available at the majority of reserves. This information is used to select districts of location, contours and routes of permanent profiles, transects, permanent recording plots, pheno-stations, and other stationary establishments which reflect the main aspects of natural conditions in a reserve: latitudinal zonality, altitudinal zonality, types of vegetation, diversity of topography, age variation, etc. The system of permanent observation sites is built in order to obtain information which is sufficiently representative with regards to the studied plot and

which allows the findings and survey material to be extrapolated to an appropriate region. A permanent profile characterizes the natural complex of the relevant district and is the key plot for studying seasonal, annual, and long-term changes in nature. The permanent observation plots are used for geodetic survey, a detailed description and mapping of the soil cover and vegetation is carried out, the mesofauna and other indicators which are on the program of the integrated biological inventory are recorded (biosurvey). Such full biological surveys are repeated, as a rule, every 5 years and make it possible to monitor the variablity of structural characteristics of the cenosis: The growth and development of cenosis-forming species, the dynamics of growth and dying off of different phenorhythmotypes, the rhythmicity of the bioproduction process in the cenosis, the variability of indicators at different levels of the cenosis, and other parameters. Besides the annual biological surveys, there are regular observations of the components of the biocenosis as well as seasonal changes in a number of enviornmental factors including the rhythmicity of some characteristics. These are conducted along the profile and at permanent observation sites. They include hydrological and hydrogeological observations, snow surveys, the study of the circulation of nutritive elements and their loss with runoff waters, the determination of the biological productivity of censosis, ecological-physiological studies, etc.

The indicated methods of integrated permanent studies make it possible to discover and appraise the structure, the laws of functioning of ecosystems including the quantitative and qualitative relationships within the ecosystem components, the succession stages, time periods for restoration, the ability for a given standard of productivity, and other characteristics.

Permanent monitoring of the animal populations is also conducted along pathways of regular movement, at places of their regular accumulation, and on other plots where comparable and continuous results can be obtained. It is difficult, however, to speak of techniques for using this type of data for a full population characterization of species which are very mobile and migratory.

Permanent biogeocenological studies are well developed at some reserves of the Soviet Union. The Caucasian Reserve has included, in a network of integrated permanent sites, all representative and unique phytocenoses in the areas of populations of most important relict forest-formers in the three meridional ecological-geomorphological profiles spaning the Main Caucasian Ridge (vertical zonality-from 600 to 3 200 m). A similar system of permanent, integrated observation sites has been established in Sikhote-Alin, Altai, Teberda, and some other mountain reserves. A diversified network of integrated biocenological permanent observation sites has been established at the Voronezh, Central-Forest, Khoper, Oka, and other lowland reserves.

Monitoring the state of the plant cover at the comparatively small Priokso-Terrace Reserve is based on a system of permanent observation sites combined with regular detailed territorial examinations which make it possible to trace changes in different types of successions and fluctuations over many years.

The integrated studies at permanent observation sites at the Astrakhan Reserve conducted for many years on ecological-geomorphological profiles in the Volga river delta and in the coastal band of Northern Caspian provide interesting data on the hydrogeological regimen, geomorphological characteristics, and present state and the changes in the hydro- and land-surface vegetation. They also provide data on aquatic and terrestrial animals in the periods prior, during, and after establishment in the conditions of a regulated Volga river discharge.

In order to better evaluate and manage ecosystems and to find methods of early diagnosis of ecologically significant changes (pollution) of the environment and biosphere, studies of bioconcentrating and sensitive indicator species of plants and animals are conducted in a number of reserves. The Central-Forest Reserve is using contemporary ecological morphology and physiology of plants to evaluate the state of the plant cover in the taiga biota. The associates at this place make use of these species which are decisive in the plant cover. The sensitivity of coniferous species to atmospheric pollutants makes it expedient to study the structural and functional characterisitics of spruce trees which might be of indicator significance.

The associates of the Caucasian Reserve are collecting data on the reproductive and regenerative ability of the cambial activity and other bioecological properties of some plants which are sensitive to environmental changes.

The soil fauna and insectivorous predators are studied among the organisms studied as possible model indicators by the associates of the Central-Forest Reserve. The idea is that the state of soil-inhabiting invertebrates, which are characterized by their close relationship with the physical and chemical regimens of soil, might be used for recording the influence of different soil pollutants. Soil fauna include animals at different trophic levels, and this affords the possibility of evaluating the effects on and dynamics of number, fertility, population structure, etc.

The state of insectivorous predators, while consuming other species which cummulate definite pollutants, may also give information on the circulation of these substances in nature. The short life cycle, intensive metabolism, and lability of the main morphological and physiological indexes of shrews makes them a particularly attractive indicator species.

The studies in some reserves cover the behavior of individual radionuclides in the biological circulation of matter and their action upon the growth and development of plant and animal organisms. Several animal species have been singled out for their active cummulation of radionuclides and as possible indicators of this type of environmental pollutant.

CONCLUSIONS

The content and the orientation of research at Soviet state reserves makes it possible to consider the reserves as unique natural laboratories which possess a network of native "instruments", native "proving grounds", which are sensitive to any changes in the biosphere. Scientific work at reserves is subordinated to the task of obtaining information on the state and dynamics of natural systems and their components under different conditions of development. It is conducted by continuous and periodic studies on the state of the environment and elements of the biosphere. A system of permanent biological observation sites, which reflect the diversity of natural conditions, ensures the reliability of averaged indicators for the entire territory of a reserve and their adequate representativity as related to the biome.

The network of state reserves in the U.S.S.R. which are located in the main biomes of the country might be used for the investigation of the influence of pollution on terrestrial and fresh water ecosystems and for monitoring the level and behavior of pollutants in the selected components of those ecosystems.

The state of the environment--air, water, soil, etc--at most of the reserves is still not being recorded completely in accordance with basic and unified indicators which provide for the identification of the necessary parameters of pollution. The state, distribution, and population dynamics of the main species of animals and plants, in most reserves, however, has been studied in keeping with a uniform program for 30-50 years. Some of the reserves have singled out individual indicator species of those animals and plants which are most labile and which respond actively to environmental changes, therefore making it comparatively easy to record the changes in their organisms.

The organizational structure and management of reserves provides for territorial zoning and differentiated operating conditions, ensuring: (1) the maintenance of natural processes in a considerable portion of the territory; and (2) the possibility of implementing measures for the protection, restoration, and regulation of disturbed natural relationships.

The regimen at reserves and the zonal-geographical principle of their location throughout the country ensures the advantages for the organization of monitoring the background state and changes of the biosphere in the given region. The main task is not the formulation of the techniques of biosphere studies because new methods might be developed at reserves; the most important thing at this moment is to establish a system of biosphere reserves as the foundation for the studies and for the preservation of the genetic diversity of the biosphere.

It should also be noted that the term "biosphere reserve" should not be applied to territories without reserve status. The varied forms of monitoring stations are not identical with the content of operation of biosphere reserves and cannot be expected to replace them.

Research at Biogeocenological Stations in Deserts — A Link in the Biosphere Monitoring System

by

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Deserts in the Union of Soviet Socialist Republics (U.S.S.R.) cover a vast territory of 200 million hectares--approximately 10 percent of the country's total area. This is mostly virgin territory where natural resources have not been fully developed.

Varying natural conditions of the arid region are represented by different types of deserts. A network of biogeocenological stations sufficient to encompass the diversity of at least the main subdivisions of the desert biome would be the ideal situation. This is, however, often not the real situation. Also, although there is a rather large network of stations in the arid zone of the U.S.S.R., not all of them conduct biogeocenological research (table 1).

Table 1--Biogeocenological stations and permanent desert monitoring stations in the U.S.S.R.

	Location, Name, and Natural Conditions	Year Established	Agency
1.	Repetek-Desert-Sand Station with a "Zapovednik". Eastern Kapakums, white and black haloxylon.	1912	Institute of Deserts, Academy of Sciences of the Turkmen SSR.
2.	Karakum Station/Karra-Kul/Takyr Range of the Central Karakums. Large shrub associations in sands and semi-shrub associations in the Takyrs.	1960	Institute of Deserts, Academy of Sciences of the Turkmen SSR.
3.	Tereskent Station, Northern Arals, wormwood in greyish-brown soils, sand.	1965	Institute of Botany, Academy of Sciences of the Kazakhstan SSR.
4.	Takum Station. Southern Balkhashes Shrub and grass associations in sand.	1965	Institute of Botany, Academy of Sciences of the Kazakhstan SSR.
5.	Kizilkum Station. Western Kizilkum. Shrub and semi-shrub associations in gypseous desert.	1959	Institute of Botany, Academy of Sciences of the Uzbekistan SSR.

The deserts are an arena of highly specialized life under extreme conditions, conditions near the limit for possible existence of developed communities. At the same time, deserts are areas where the potential biological productivity of biogeocenoses is rather high. Therefore, it is an urgent task to understand the laws of life in the desert zone so that this information can be used as a baseline in developing integrated biological systems for amelioration and rational use of biological resources of the desert.

SPECIFICS OF DESERT BIOGEOCENOSIS

The following features of desert biogeocenosis are important distinguishing features: (1) environmental peculiarities, particularly the climate (abundance of solar energy, high temperatures, scarce precipitation, etc.); and (2) the peculiarities of biological cycles of ash elements and nitrogen, due to the rapid decomposition and mineralization of organic detritus in a situation where there is practically no litter and humus accumulation is negligible.

The biogeocenosis includes most varying forms of plants, animals, and microorganisms with different adaptations to unfavorable environmental conditions. The entire life of biogeocenosis goes under extreme conditions, with very sharp variations in the differing factors. Seasonal and annual fluctuation of all vital processes are pronounced. A definite part of the territory occupied by a developing biogeocenosis, particularly in the sand desert ("barkhan" sands).

The desert biogeocenoses, have had a long history of formation. They represent mature self-regulated systems with strongly interlinked biotic and abiotic elements. These connections maintain the long-term existence of biogeocenosis within definite average parameters. The unavoidable, and sometimes considerable, variations in total productivity ususally level out rather quickly and the entire system soon approaches the average value.

It is of utmost importance to determine the average values of a number of parameters for many years (the number of plant and animal species, their biomass, etc.). It is also important to ascertain the reasons for both their average fluctuations and limits. For example, since vegetation is used as livestock feed, it is important to know the size of crop yields for various types of pasturage and their annual fluctuations. It has been established that all phytomass production and year-to-year fluctuations, due to meteorological factors, are linked to the composition of vital plant forms on various types of grazing land. The general phytomass (dry weight, kg/hectare) of large-shrub associations makes up 80.7 (surface-37.5, subsurface-43.2); small-shrub associations 51.2 (surface-28.0, subsurface-39.4); semi-shrub associations 51.2 (surface-32.5, subsurface-18.7); grass associations 29.2 (surface-4.5, subsurface-24.7). Thus, vegetation cover, consisting of highly organized biomorphs, seems to be most productive (fig. 1).

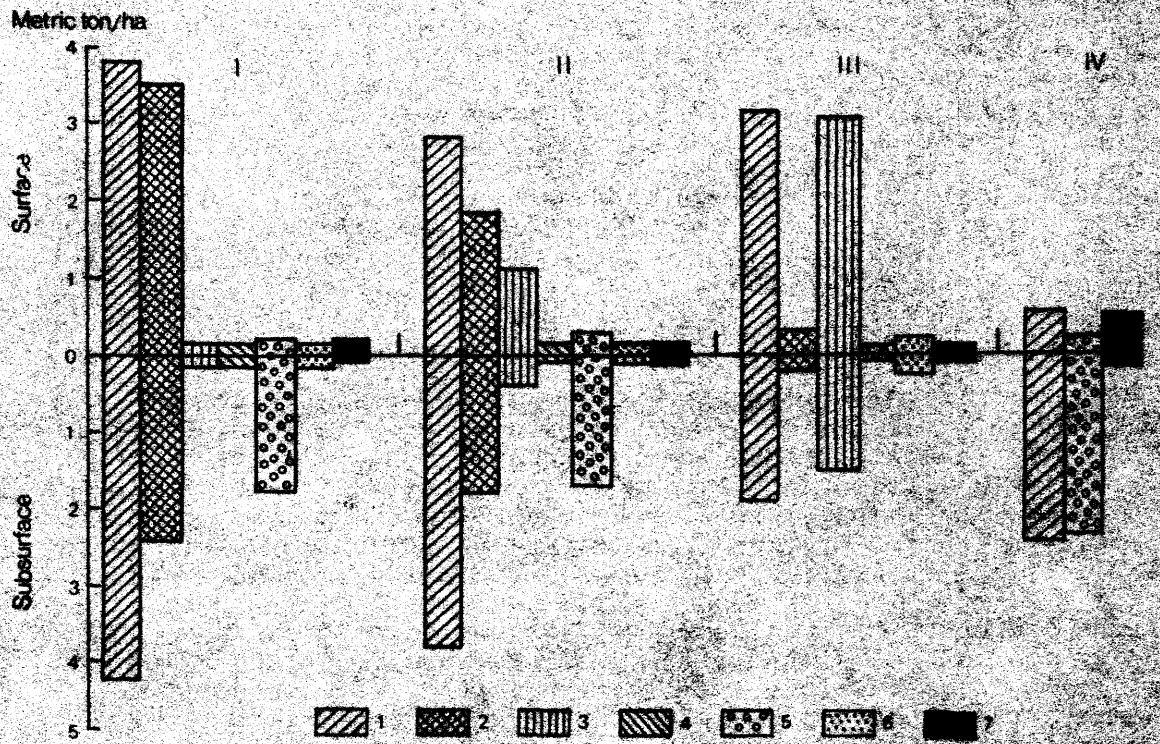

Figure 1.—Phytomass structure of desert phytocenoses, related to vital form content. I—Large shrub associations (*Haloxylon persicum – Carex physodes* ass.); II—Small shrub (*Salsola arbuscula-Artemisia, kemrudica-Carex physodes* ass.); III—Semi-shrub (*Salsola gemmascens + Artemisia kemrudica* ass.); IV—Grasses (*Carex pachystylis + Poa bulbosa* ass.). 1 — Total phytomass; 2—shrubs; 3—semi-shrubs; 4—perennial summer-fall grasses; 5—perennial winter-spring grasses; 6—annual summer-fall grasses; 7—annual winter-spring grasses.

Long-term average yields of annual sprouts (feed) is close for all types and comprises 4.7-4.5 kg/h, while year-to-year changes, due to weather conditions, are varied: they are less pronounced in shrub associations, where species with well developed perennial surface organs dominate, and more significant among the grasses (fig. 2). These patterns have great significance for desert animal husbandry, based mainly on natural grazelands.

Induced disruption of the biogeocenotic links, such as a sharp intensification or weakening of any component, invariably causes certain rearrangements within the biogeocenosis; the intensity of the readjustment increases with the importance of the altered factor in the life of the biogeocenosis.

Biogeocenoses are subject to regular changes owing to their natural age; the most essential present changes, however, are those depending on anthropogenic influences. At the present time,

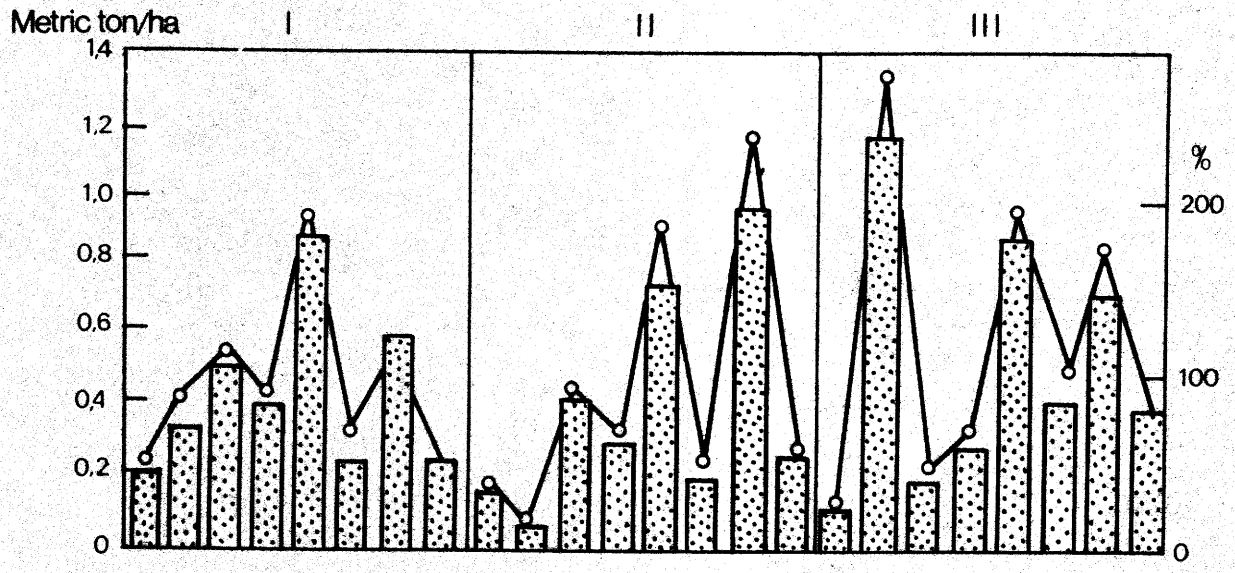

Figure 2.—Crop Dynamics (1960-1967). I—Large shrub associations *(Haloxylon persicum-Carex physodes* ass.), M = 0.47 (100%), lim = 0.26-0.92 (55-195%); II—Semi-shrub *(Salsola gemmascens + Artemisia kerudica* ass.), M = 0.45 (100%), lim = 0.08-1.05 (17-234%); III—Grasses *(Carex pachystylis + Poa bulbosa* ass.), M = 0.45 (100%), lim = 0.13-1.23 (29-273%). Columns = harvest, T/h; Curve - harvest fluctuations (%).

all deserts are undergoing rapid changes owing to intensive geological and hydrological surveys and mechanized development of mineral resources.

Engineering staffs, unaware of desert ecology needlessly destroy nature. Examples of this are the numerous unwanted roads built in deserts and the destruction of takyr surfaces by motor transport which has disrupted their role as water drainage systems. Excessive cattle grazing and shrubcutting for fire wood cause considerable disruptions. All this is due to underestimating the sensibility of desert ecosystems which function in extreme conditions and are extremely responsive to quick and irreversible changes.

The structual transformations of biogeocenoses, due to economic utilization of desert territories, has to a considerable degree superceded in both speed and intensity evolutionary changes of the biosphere; in some instances this activity produces catastrophic consequences. However, technical means in a planned socialist economy afford great possibilities for developing desert zone resources and for realizing scientific management in the economic exploitation of deserts. These great and urgent scientific tasks place the integrated, biogeocenological study of desert ecosystems as a first priority.

MAIN TASKS OF BIOGEOCENOTIC STUDIES

Understanding the operational mechanics of biogeocenoses as single systems is imperative as the danger of disrupting the natural equilibrium in an arid zone is approached.

Integrated biogeocenological studies offer the theoretical basis for developing rational management techniques. This knowledge of natural ecosystems makes it possible to avoid sharp, undesirable, and in many cases, irreversible dislocations as well as to work out techniques for active and meaningful intervention into biogeocenoses for their enrichment and increased biological productivity.

Since times immemorial the deserts have been used as pastures and desert shrubs as sources of firewood. However, the balancing of consumption and conservation of natural resources has not been accomplished.

Domestic animals, specifically sheep and camels, graze the deserts throughout the year and together with wild fauna, are consuming food resources. Cattle influence ecosystems more than wild animals by removing more vegetative mass, introducing their own by-products, and mechanically influencing the pastures. Domestic animals in the arid zone should, therefore, be regarded as ecosystem components equal to wild animals and as the main consumers of primary production. The long-term task of increasing the productivity of pasture-based livestock cannot be solved without theoretical studies based on the anlysis of the consumption of the vegetative mass by different animal species--both wild and domestic.

Biogeocenological studies are based on long-term observation and experiments at permanent stations. The station-based studies of recent decades have greatly contributed to national economy. Rational methods have been developed for the use of grazing lands, improvement of pastures, yield forecasting, improvement of non-irrigated meadows, techniques of fixing and aforesting sands, melioration of mountain slopes, suppressing natural foci of infections, etc.

One of the main ways to conserve natural resources on deserts is to use rational methods for livestock breeding and for extraction of mineral resources. It is understandable that Reserves, which are necessary for the protection of valuable species of animals, plants and intact landscapes, cannot cover very large areas.

It should also be noted that the protected natural landscapes are not always the most productive ones. Moderately grazed territories frequently produce large amounts of plant mass and are known for good plant reproduction. Improved pastures, even without irrigation, have much better yields than Reserve territories. Nevertheless, Reserves are most convenient and indispensable for the protection of rare species of plants and animals and for theoretical research. They serve as reference points for the

productivity of biogeocenoses under different utilization regimes. The biogeocenological studies at all stations should be conducted in keeping with the following pattern: Reserve--anthropogenic variants--cultural biogeocenoses or agrocenoses (irrigated or nonirrigated). Comparative studies of ecosystems under different conditions will more quickly produce recommendations for practice.

PROGRAM OF BIOGEOCENOLOGICAL STUDIES AT THE STATIONS

The study of vital biogeocenotic processes is recognized as a pressing scientific task. The understanding of the structure and functioning of biogeocenoses as self-regulated systems--as fundamental subdivisions of the biogeocenotic cover--is the theoretical foundation for the rational utilization and conservation of the earth's biological resources.

Modern scientific and practical requirements necessitate the study of the entire set of measures relevant to rational utilization, conservation and enrichment of desert ecosystems. Naturally, the major branch would be livestock breeding. Other important aspects are sand fixation, planting of greenery in industrial districts, the special nature of desert forestry, etc. Comprehensive knowledge of the biogeocenosis is indispensible for all these measures. The study of all components of biogeocenoses, and of the balance of element circulation, is most difficult and requires the participation of different specialists. Therefore, attention should initially be drawn to the comparatively simpler questions of secondary and primary productivity.

The main sections of a study program at biogeocenological stations in the desert zone should be as follows:

1. Structural-functional organization of natural biogeocenoses under different utilization regimes. This includes the study of: (a) The matter-energy resources. It should be stressed that the consideration and evaluation of special environment features of living organisms in biogeocenoses is particularly important. This is because of the diversity of ecological conditions, including the great variety in the mechanical and chemical composition of soils and parent rock and the considerable range and sharp annual and seasonal fluctuations in climatic conditions. The products of a biogeocenosis (phytomass, zoomass, etc.) and its life are totally dependent upon a set of interrelated natural factors. These relationships are poorly known and are much more complex than it is sometimes believed. (b) Biological resources. This is an extremely important division of study which helps to evaluate the biotas (the living component) of biogeocenosis with regards to their modal composition, bioforms, and adaptation to arid conditions with consideration for energy and metabolism.

Understanding the structure and productivity (primary and secondary) of natural biogeocenoses in their seasonal and annual dynamics are included here. This covers the study of: pasture reaction (vegetation and soils) to grazing; changes in the species

composition, associations, and productivity; the recreation of vegetation in relation to the influence of grazing upon the soil cover; and the destruction of seeds and sprouts.

2. Elaboration of methods for enriching biogeocenoses. Two methods of increasing biological productivity should be considered--vegetation improvement and faunal enrichment.

Measures for improving pasture vegetation include plant introductions, improved techniques for creating cultivated pastures, seed production, and selection of newly cultivated plants. The improvement of desert pasture with very low precipitation is based on the knowledge of plant ecology and different ways of accumulating moisture for better utilization of precipitation. An important segment is studying the horizontal and vertical structure of artificial phytocenoses, their productivity, and species composition and structure, as compared to natural biogeocenoses and anthropogenic variants.

A special concern is wind erosion control in sand deserts by using artifical covers and phytomelioration.

3. Rational utilization of pastures. This includes: appraisals of chemical composition and nutritive values of definite types of pasture forage and rations; compositional analyses of wild animals (insects, rodents, ungulates) as well as sheep and camel nutrition; reactions of different plants to shoot removal by animals; and influences of different grazing intensities.

Methods of determining the indices of optimal utilization of pastures and the maximum allowable burden upon ecosystems belong in this area as does improved techniques for pasture utilization under combined grazing of different species of cattle.

Other subjects requiring study are the improvement of pasture rotation systems (alteration of the season of utilization by years) with an optimal load, better techniques for keeping sheep in fenced pastures, the combined utilization of natural pastures with additional feeding of coarse and concentrated foods, and improved systems of pasture use and other techniques for further intensification of desert sheep husbandry.

4. A final section of the research program should be the improvement of domestic animals on the basis of selection, better feeding and keeping of animals, an improved fodder base, better use of remote and poorly watered territories, and the maximum, non-damaging utilization of desert ecosystems.

CONCLUSIONS

The protection of the environment and rational management of biological resources is an important human concern. In the U.S.S.R. both matters are urgent owing to the need to develop sheep breeding and improve productivity.

The study of the man-environment relationship in all its diversity is the substance of the International Man and the Biosphere Program (MAB). The growth of the population necessitates improvement in economic activity to increase the productivity of farmland. To bring this about one should understand the motive forces of biogeocenoses, their dynamics and regulation. The MAB Program should underlie modern agricultural science and practice. As L. I. Brezhnev said in 1974 in Alm a Alta, "Agriculture is in need of new ideas capable of revolutionizing farming production. . ."

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Soil as a Component of Natural Ecosystems and the Study of Its History, Modern Dynamics and Anthropogenic Changes

by

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The study of natural ecosystems at biosphere station-reserves must include the following mutually supplementing directions in soil research:

1. Investigation of the stable, conservative properties (composition and organization) of soil and the soil mantle; actually, this is the study of soil as a product formed over a long period of time due to self-development and evolution of natural ecosystems.

2. Investigation of modern dynamics (functioning) of soil and its anthropogenic changes.

The present paper assumes that biosphere stations will be situated mainly on the territories of natural ecosystems in a dynamic equilibrium with the environment.

In accordance with this assumption, our subsequent reasoning is based on the probable, but not yet proven, concept of a mature or quasi-equiponderant (developed, normal, climax) soil (Kossovich 1911, Rode 1947, Jenny 1948, Gerasimov and Glazovskaya 1960). A mature soil can apparently be only a component of a mature (quasi-equiponderant) ecosystem (Dokuchaev 1964, Sukachev 1972, Rode 1947). This concept is associated closely with the ideas about self-development and evolution of soils.

THE SELF-DEVELOPMENT (MONOGENETIC DEVELOPMENT) OF SOILS

The self-development of soil is understood most frequently as a process of soil body (profile) formation under invariable environmental conditions which start from "time-zero". Complete self-development results in the formation of a mature quasi-equiponderant soil body. The self-development of soil is regarded as a constituent part of the self-development of a natural ecosystem under invariable environmental conditions (Kossovich 1911, Rode 1947, Gerasimov and Glazovskaya 1960, Sukachev 1972, Kovda 1973). The

latter primarily include macroclimate and macrotopography. The formation of a mature soil in different climatic zones is known to require from several hundred to tens of thousands of years. Even within hundreds and thousands of years, however, not all the properties of soils settle into a complete equilibrium with the environment and, therefore, slowly continue to change. But such properties are not of prime significance for the formation of the corresponding type of soil. The mature soils, whose self-development occurred under invariable environmental conditions and, as part of a syngenetically developing natural ecosystem, are called monogenetic (Thorp 1965, Kovda 1973). Time necessary for a monogenetic soil in order to achieve the quasi-equiponderant status is called the relative age of soil (Williams 1950, Gerasimov 1969).

From the viewpoint of biogeoceonologists and ecologists (Sukachev 1972, Odum 1975, and others), a natural ecosystem can be considered mature when its biotic part settles into dynamic equilibrium with the enviornment. But soil - a component of the natural ecosystem - develops more slowly than vegetation and animal life. Even under the influence of a quasi-equiponderant ecosystem, soil continues to develop and move towards a complete equilibrium. Due to feed-back, this results in a slow change of the biome. Thus, a more complete equilibrium of the natural ecosystem occurs with the formation of mature soil.

It is expedient to distinguish between an individual, mature soil profile in a point and the mature soil mantle in a given ecosystem. The latter, along with mature soils, can contain plots of immature, non-equiponderant soils. The immaturity of these soils is regularly maintained by processes organically inherent to the given ecosystem (windfalls, activity of burrowing animals, cryogenic disturbances, etc.).

THE POLYCLIMAX OF SOILS

At present, science recognizes that under similar climatic conditions several climax biocenoses, with their respective soils, are formed. The soil polyclimax results from the fact that soils are formed due to the interaction of equally effective and significant factors of soil formation (excluding climate) such as the topography and parent rocks. This plurality of mature soils (polyclimax) appears under conditions of similar climate in those cases in which there are significant differences in the character of topography and/or parent rocks. In the course of development there occurs a partial convergence of soils developed in different lithological-geomorphological conditions which is never complete.

The above considerations compel one to conclude that in natural ecosystems with similar macroclimate the formation of a certain spectrum of mature soils, rather than one mature soil, is typical.

THE EVOLUTION OF SOILS

In most cases the occurrence of mature monogenetic soils is more myth than reality. There is simply not enough time for all, or even most, soil properties to reach quasi-equilibrium. For instance, the soils of glacial and periglacial areas of the Russsian Plain are of Holocenic age, i.e. they are about 10,000 years old. At the same time, even if the general conditions of climate and topography remained constant for a sufficiently long period of time, the denudation and eolian transportation of substance constantly supplied new portions of immature material to be involved in the soil-forming process. Even during the Holocene, however, natural-climatic conditions markedly changed.

Thus, during the Holocene, the processes of self-development of soils were to a certain extent maintained in the process of soil formation and there occurred the processes of "induced" development of soils that followed the changes in the natural-climatic conditions. The change of soils which follows the changes in the external factors of the environment is called the evolution of soils.

The conditions required for a "pure" monogenetic development of soils rarely exist. The polygenetic soils which survived several (two and more) periods of monogenetic development are usually in non-tropical areas.

SOIL IN A NATURAL ECOSYSTEM

The condition above makes it possible to consider soil as a very complicated component of ecosystems, as an open subsystem requiring different approaches and methods of investigation (Rode 1971, Jaalon 1970).

On the one hand, a mature soil (its composition and organization) in "to-day's" ecosystem is the product of activities of not only "to-day's" ecosystem but of all the preceeding ecosystems which existed on the given territory since the earliest appearance of vegetation, i.e. from the beginning of soil formation. Mature soil observed in "to-day's" ecosystem had to inevitably survive all the stages of monogenetic development and long natural evolution on a given site, unless soil outwash or burying occurred (Polynov 1930, Gerasimov and Glazovskaya 1960, Kovda 1973). Therefore, a mature soil profile and its stable conservative properties must be considered the "memory" of both self-development and evolution of landscapes (Targulian et al. 1974, Armand 1975, Sokolov and Targulian 1976). The processes of the last monogenetic stage can completely, or partially, eradicate the features of the former processes or be superimposed on them.

On the other hand, a mature soil profile is not only a "preserved" memory of the former processes but also the most significant material basis, the dynamic "component" which directly takes part in the functioning of today's ecosystem. In this sense, it is

possible to speak about "life" of a mature soil or about its dynamics.

The realization that soil is a long-formed product (memory of self-development and evolution) and a "living" continuously functioning component of today's ecosystems both determine the general approach to the investigation of soils at the biosphere stations.

The investigations of soil statics (composition, profile organization) are significant as the basis for memory deciphering and for the understanding of contemporary processes, even though they cannot explain completely today's work of an ecosystem and the role of soil in this work. Similarly, the investigation of the current life (i.e. modern dynamics) of a mature soil in the ecosystem does not fully explain its genesis, i.e. its path of development in time, starting from time-zero and up to the present, and the mechanisms which have brought about its present condition.

Each of these two directions of investigation has its theory and methods. And it is only by combining the results of investigations in these two directions that one can obtain full and versatile knowledge about soils at the biospheric stations which can be regarded as standards for observing nature and its anthropogenic changes.

THE INVESTIGATION OF STABLE, CONSERVATIVE PROPERTIES OF SOIL AND THE SOIL MANTLE

The tasks of such investigation are diverse. They involve: (a) description of the object, i.e. the cognition of morphology, substance composition, and organization of the solid phase of a soil body; it is obvious that this work will demand application of the majority of contemporary methods of investigating territory and substance; (b) determination of the dependence of soil composition and organization on environmental factors (both the outer ones, with respect to the ecosystem, and the inner ones); (c) elaboration of the soil genesis concept. This complete genetic concept should be based on the understanding that mature soil results not simply from the interaction of factors and mechanism of soil formation, but also from a certain historic (temporal) succession of these interactions. Such a concept is based on a series of particular empirical hypotheses concerning the essence, set, spatial distribution, and temporal succession of the elementary soil-forming processes (ESP). This task can be considered the most significant in the study of soil- "memory".

A promising approach for the study of stable, conservative soil properties and mantle is one based on the concept of a hierarchy of organizational levels of soil body components (table 1). Investigation at each level permits us to disclose its characteristics and internal regularities (Rozanov 1975).

Table 1--Basic levels of soil organization and methods of research

Level of organization	Method of research
1. Pedosphere	Presently not yet under investigation at Biosphere Reserves.
2. Soil mantle	Surface cartographical, aerial methods of investigating the structure of the soil mantle. Terrain - geochemical methods of studying geochemical soil conjugates.
3. Soil profile	Field macro-, meso-morphology; morphometrics; field physical and chemcial techniques; profile experiments as a whole.
4. Soil horizon	Macro-, meso-, micro-morphology (optical and scanning microscopy), material composition and characteristics of the general mass of the horizon (granulometrics; chemistry; bio- and physio-chemistry; mineralogy, etc.).
5. Soil aggregate	Mezo- and micro-morphology (optical and scanning microscopy); sample analysis; material composition and characteristics of the ped parts; micro-probe analysis.
6. Crystal, molecule	X-ray, X-S; spectrometrics; electron microscopy; micro-probe, chemical and other analyses of the composition and transformation of minerals, amorphous organo-mineral and organic substances at the crystal and molecular levels.
7. Atom-Ion	Chemistry and radio-chemistry of isotopes in the soil; sprectrometric and chemical methods of studying ion exchange and ion migration in the soil.

Investigations of organizational levels of soil bodies is not just a "privilege" of the first research direction soil memory studies; they can also be carried out during current soil life studies. For the first research direction, the most important studies appear to be investigations (without omitting levels) of the composition and organization of soil, as a basis for genetic hypotheses, related to "processes" and "time". Although the study of stable, conservative soil properties and the formation of genetic concepts are important, it still does not answer these questions: (1) what in the soil body observed today exists as a product of present processes and what of past, that have already ceased or

are extraordinarily slow; (2) are presently observed soils mature and "working" in a dynamic equilibrium, or do directional processes continue to function within them; (3) what are the nature and quantitative characteristics of current processes.

Only after these questions have been answered, can we reveal the tendency of current soil development in natural ecosystems and forecast the future. These tasks are being resolved by studying the current life (dynamics) of soils and the soil mantle.

THE INVESTIGATION OF THE CURRENT "LIFE" (MODERN DYNAMICS) OF SOIL AND ITS FUNCTIONING IN TODAY'S ECOSYSTEM

From all of the combined processes of soil formation, it is possible to single out the following groups:

1. The cyclic processes. They are characterized by a periodic return of the system to one and the same or to a very close status. The duration of periods remains constant. This is associated with the fact that the duration of cycles and their superimposition over each other (diurnal, annual, etc.) are determined primarily by general planetary factors.

2. The arbitrary or quasi-periodic processes. They are characterized by a periodic return of the system to an analogous status in time intervals of arbitrary duration. Obviously, it is possible to regard as arbitrary some reversible changes of forest soils (humus content, thickness of litter) depending on which part of the tree crown (near to the stem, crown edge or "window" between the trees) at a given moment is over the profile under investigation.

3. The trend (directed processes). This represents those changes, during which the system status is not repeated in any time scale. In a humid climate, the removal of dissolved compounds outside the soil and ecosystem is related to such processes. The direction of the process is preserved for long intervals of time (hundreds and thousands of years), and very short periods (one day).

The groups of processes usually occur in soils and ecosystems in complex combinations. Frequently, the cyclic and directed processes combine. Such a "hybrid" process consists of a series of cycles which are not completely closed and, therefore, at the end of each cycle, the system status changes by a small residual value. The accumulation of these values gives rise to the directed change in the soil properties trend. To these processes belong: humus accumulation in soils, differentiation of the majority of elements in the soil profile, leaching out or salinization in semi-arid conditions, etc. The arbitrary (quasi-periodic) processes superimpose in natural conditions the first two types and their combinations. When studying the cyclic and quasi-periodic processes, it is important to bear in mind that both the direct and inverse phases of these processes can be: (a) not identical in their nature (absorption of short-wave and emission of long-wave radiation by soil); (b) separated in time and space (descending chemical migration and ascending biogenic migration of elements); (c) different in rates (supply and decomposition of litter-fall).

THE CHARACTERISTIC TIME

Each process can be related to a characteristic time (C.T.) (Armand and Targulain 1974). By the C.T. we understand: (a) duration of the period for the cyclic processes; (b) the average duration of the period for the quasi-periodic processes; and (c) time needed by the system for the restoration of the quasi-equilibrium disturbed by the outer influences - for the trend processes. Every component of an ecosystem, considered from this viewpoint, is represented by a complex of systems with different C.T. Moreover, the changes of every variable characterizing the states of soil components can be determined by a broad spectrum of C.T. Apparently, C.T.'s which correspond to the maximum amplitudes of changes should be regarded as the main ones. For such properties as moisture content of soils, pH, and others, the values of C.T. will be of the order of 10^{0} - 10^{-2} expressed in days, seasons, groups of years; for the contents of humus and clay they will amount to 10^{2} - 10^{3}, i.e. to hundreds and thousands of years and for mineralogical profile to - 10^{5}, i.e. to tens of thousands of years.

When investigating the dynamics of the current life of soil, one should also take into consideration the hierarchy of characteristic times of the processes occurring in soil. Not infrequently the C.T. of processes is determined by the phase states of substances in which these processes occur. The processes occur most rapidly in the gas phase, more slowly in the liquid phase and on the interface between phases, and most slowly within the solid phase.

In order to study its present life, it becomes particularly important to view soil as a unique link in the natural ecosystem, inextricably tied, to all other links. To qualify this, we propose that each group of soil observations be related to observation on other components of the ecosystem. In table 2 this proposal is introduced in columns 5 and 6 at a very preliminary level.

Table 2 permits us to divide the approaches for studying soil and the natural ecosystem as a whole into two groups: direct study of regimens for "fast" processes and indirect study of "slow" processes via the results of those processes. This proposed division of the concepts "life" and "memory" (stasis and dynamics), as related to soil, are entirely conditional. Real soil is an unbreakable chain of interrelated processes, ranging from the incredibly "fast" to the very "slow". An operational division of processes into two groups can, however, be set up for those unfinished processes. Those processes which afford direct observations of functions can be ascribed to the soil's "life", all others to it's "memory". Further study of soil regimens should permit us to separate present "directional" process from those which have attained dynamic balance or have either culminated or become exceptionally slow.

SPATIAL VARIABILITY OF PROPERTIES IN A NATURAL ECOSYSTEM

Practical research on the temporary changeability of soils encounters considerable complications related to the spatial

Table 2--Characteristic times of several biogeocenological processes and their study

CT	Atmosphere	Live organisms	Soil	Studied characteristics		Techniques
				Non-soil	Soil	
1	2	3	4	5	6	7
10^6	Climatic fluctuations in the pleistocene		Formation of mineralogically, chemically & morphologically differentiated soil profile	Macrotopography, geology of fundamental & quaternary rock	Morphology, content & organization of the soil's hard phase	Paleographical methods; comparative geography; comparative soil horizon analysis
10^4	Same in the Holocene			Climate & vegetation history		
10^3	Same in the historical period		Formation of the humus profile	Mesotopography, geology of quaternary deposits		
10^2	90-yr. Climatic cycle	Formation of forest biocenoses	Biological soil cycles; quasi-cycles	Forest edificator composition artifacts	Soil horizon thickness, reserves of organic matter & ash elements	Constant observation
10^1	Solar cycle	Formation of grass biocenoses and large animal populations	Salt profile. Profile of exchange cations	Phyto- and Zoocenosis composition	Balance of organic matter & ash elements. Artifacts. Filtration capacity. Transposition of the hard phase	
10^0	Meteorological cycle	Formation of rodents, insects and others	Formation of a profile of easily dissolved matter; pH, OVP, etc.	Balance of moisture, heat, biomass. Activity of burrowing animals. Exogenous substances	Annual balance of "litter", roots. Composition of soil solutions. Content of various chemical elements	Constant observation
10^{-1} mo.			Hydrological & temperature soil profiles	Precipitation, air temperature, snow cover, phenophases of plants and animals, drainage	Ground water levels, humidity, frost, ground temp. to 1 meter. Composition of soil, air, pH, EH, pF.	
10^{-2} days	Daily meteorological cycle	Daily biocycles		Air temperature, radiation, precipitation, transpiration	Temp. and humidity at depth of 30-40 cm, soil respiration	

variablity of properties and processes in a natural ecosystem's soil mantle. Spatial changeability of soils is brought about, on one hand, by past "inheritance", (by heterogeneity of soil "memory") and, on the other, by present spatial differentiations of a natural ecosystem's components.

We believe that the particular features of spatial variation in soil properties are fairly stable and characteristic of each "quasi-equiponderant" natural ecosystem. In this instance, research into soil heterogeneity becomes a goal in itself. The resolution of this goal has value in several respects: first of all, knowledge of spatial variabiltiy has significance for the selection of a research methodology; it permits us to define the requirements of regimen observation, in order to "uncover" real internal regularities. There is, however, still another more important substantive value in studying soil variability in various places. It is apparent that any instantaneous section of various properties of the soil of a given natural ecosystem carries information not only about its "memory", but also about the "present" life of the soil. By comparing the spatial variation of soil properties with the observed spatial structure of an ecosystem (i.e. the distribution of trees, microtopographical elements, etc.), one can evaluate to what extent individual properties reflect "memory" and to what extent they appear to be the result of contemporary processes. Subsequently, analysis of spatial variability of an ecosystem's soils aids in separating "today" from the past, in regards to both processes and masses or soil thicknesses caught up by these processes.

One of the most promising methods of solving this fairly complex problem may be the theory of casual functions, which is used to disclose the frequency structure of spatial variation of properties. This permits us to carry out a concerted search for those factors responsible for the instantaneous picture of property variation. Knowledge concerning genesis, current life, and spatial variability of natural ecosystem soils is necessary in order to understand the structure and functional operations of standard "reference" natural ecosystems of the world's biosphere reserves. Concurrently, we acquire inital information for monitoring and the development of dynamic forecasting models for natural ecosystems, subject to anthropogenic "pressure".

The program of direct observations of soils at the biosphere stations is based on the above-stated theoretical analysis and embraces the following four large groups of investigations:

I. Investigation of the soil mantle of the biosphere stations and the solid phase of soil profiles as the most stable characterisitics composing the background for regime observations.
II. Regime observations of the processes of substance and energy exchange of soil with the atmosphere, waters and vegetation.
III. Regime observation of the processes of substance transformation and migration within soil.
IV. Regime observations of the processes of horizontal redistribution of substance in the soil mantle (landscape-geochemical investigation).

The first group of investigation includes: (a) detailed mapping of the soil mantle with the use of surface and distance (aerocosmic) methods; (b) investigation of the substance composition of soil in accordance with soil horizons. This most traditional method of investigation provides the data on the chemical and mineralogical composition as well as particle size distribution of the soil. The results of these investigations serve as a "reference point" and background for observing the anthropogenic changes of soils.

The second and third groups of investigations, which are carried out in the representative "points" of biosphere stations, include the study of the following regimes and balances characterizing the modern dynamics of soil and its relationship with the other components of the ecosystem (atmosphere, vegetation, surface and ground waters, parent rocks):

1. The temperature regime of soils.
2. The heat regime and balance in soil.
3. The water regime and balance in soil.
4. The supply of dissolved substances to soil: (a) by precipitation; (b) by surface waters; (c) by ground waters (regimes).
5. The migration of dissolved substances within soil (regimes).
6. The outflow of dissolved substances from soil: (a) with surface waters; (b) with the lateral intrasoil flow; and (c) with the vertical intrasoil flow.
7. The gas regime of soil (CO_2, O_2, etc.).
8. The regimes of colloidal components of soil (composition and content of exchangeable cations, acidity).
9. The regimes of aggregate and microaggregate status of soil.
10. The regime of redox potential.
11. The regime of the contents of trace elements and heavy metals in soil.
12. The regimes of the contents of pesticides, insecto-fungicides, and other chemicals in soil.
13. The regime of the content of radioactive substances.
14. The regimes of the contents and compositon of salts and carbonates in soil.
15. The regimes of "mobile", i.e. extractable by various solvents, forms of different elements (N, P, K, trace elements, heavy metals, Si, Al, Fe, etc.).
16. The regime and balance of soil organic substance (soil humus and its separate fractions).
17. The regime and balance of organic substance in the biological cycle of the ecosystem (litter-fall, litter, etc.).
18. The regimes and balances of C, N, and ash elements in the biological cycle.
19. The regimes of the quantity and composition of soil microflora and soil fauna.

At present, the knowledge of the regimes stated in points 4, 5, 6, 11, 12, 13, 14, 15, 16, 17, 18, and 19 is the most significant for the study of the direct anthropogenic influence on the ecosystems.

The fourth group of investigations includes a series of observations to be conducted on the typical spatial combinations of soils (soil catenas, geochemical landscapes) in the biosphere stations.

These observations make it possible to study the redistribution of substances over the area which in different cases can result in self-purification (eluvial position) or in greater pollution of soils (hydrogenic-accumulative positions). The following investigations belong to this group:

1. The regime and balance of the surface flow of water, chemically dissolved susbstances and solid particles.
2. The same for the lateral intrasoil flow.
3. The transportation of substances by ground waters.
4. The regime and balance of eolian transporation of solid substances on the surface of soil.
5. The forms of migration and accumulation of substances (primarily the polluting ones) in the soil mantle.
6. The processes of transformation (sorption, precipitation, activation and inactivation) of polluting substances in soils.

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Primary Productivity Studies in Biosphere Reserves (Methods and Initial Results)

by

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INTRODUCTION

Methods of studying biological productivity (primary production, annual litterfall, stocks of standing crop, debris, and total organic matter) have been developed for specific tasks and types of ecosystems by many investigators.

Special attention was drawn to these methods during the International Biosphere Program (IBP), which were presented in a number of manuals (Remezov et al. 1963, Programme-minimum 1968, Rodin et al. 1969), and used by Soviet investigators in the IBP framework. These methods are based on the following principles: selection of a representative area (to cover a zone, a type of vegetation, biogeocenosis-ecosystem, microcenosis or parcella), establishment of registration plots, determination of standing crop parameters, and measurement of primary production of litterfall, litter, litter decomposition, etc., in different seasons. It is essential to conduct the experiment in a way yielding a full inventory of real production in a unit of time (10 days, a month, a year). The daily production is arrived at by estimation since direct determination is impractical in field conditions. The method suggested by A. A. Titlyanova (1971, 1974) is very promising. It is based on a systemic approach. "Blocks" are singled out within the grass biogeocenosis (standing crop, debris, litter, roots) and "flows" determined (increase in standing crop, arrival of debris from the standing crop block to the block of debris, arrival of litter from the block of debris to the block of litter, etc.). A system of balanced equations has been worked out to describe the mass of organic matter in the period chosen for investigation. Though the author's task is more ambitious--the study of the biological circulation in the biogeocenosis--the determination of primary production using the suggested methods can be achieved with greater accuracy. An essential factor is that A. A. Titlyanova's method takes into account full produciton of the subsurface sphere of the biogeocenosis as well. The wide application of A. A. Titlyanova's method thus far is "in statu nascendi," though there are publications about its application to the study of steppe associations (Titlyanova and Bazilevich 1975b, Bazilevich, editor 1975).

Now we shall review the studies concerning biosphere reserve areas.

FRANZ JOSEF LAND

Primary production was studied by V. D. Aleksandrova in 1966 (fig. 1). She investigated a polar desert and used her own methods (1958) of identifying living and dead phytomass; in 1970 she compared these findings against the standing crop values in other northern subzones (g/m^2, air-dry weight):

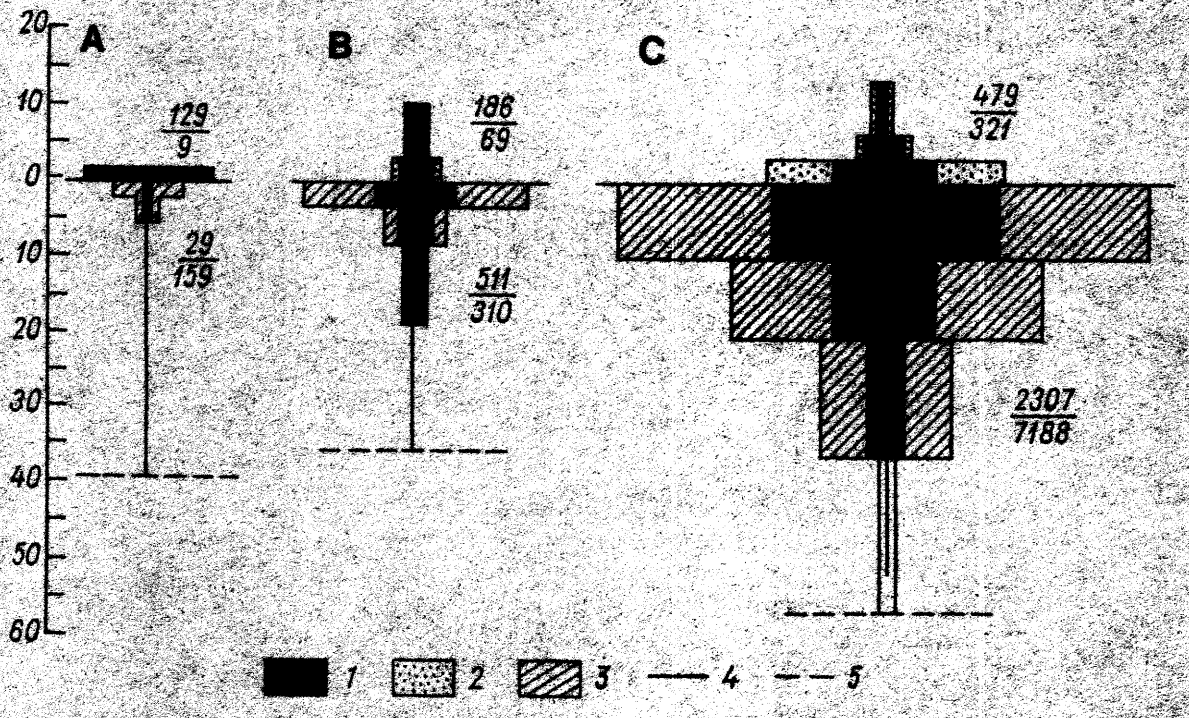

Figure 1.—Structure of vegetative mass in tundra and polar desert associations (according to Aleksandrova 1970). A—Polar Desert (Franz Josef Land); B—Arctic Tundra (Likhovskii Island); C—Southern Tundra (Koryakskaya Land). 1—live plant mass; 2—dead surface phytomass; 3—dead subsurface phytomass; 4—soil surface; 5—frost level. Numerator values = live phytomass. Denominator values = dead mass, g/m².

Phytomass	Polar desert. Franz Josef Land	Arctic tundra. New Siberian Islands	South tundra. Koryak Land	South tundra. East-European forest-tundra
Living plant parts	158	696	2 786	5 878
including: surface	129	185	479	2 162
subsurface	29	511	2 307	3 716
Dead plant parts	161	379	8 309	11 324
including: surface	9	69	521	24
subsurface	152	310	7 788	11 300
Total organic matter	319	1 075	11 095	17 200

An examination of the figures above reveals an important regularity: the surface part prevails (78%) in the standing crop of polar deserts (Franz Josef Land), whereas in the arctic and southern tundras the surface part makes up 38 and 17%, respectively.

The differences in terms of the absolute volume of all parameters are quite significant - by the order of one or two.

For instance - *total organic matter:*

Polar desert	319 g/m^2	1
Arctic desert	1 075 g/m^2	4
Southern tundra	11 095 g/m^2	35

Flowering plants (angiospermous) in the polar desert standing crop structure comprise 23%; moss and lichen make up 76%. In the Arctic and southern tundras the flowering plants account for 63 and 91%, respectively, while the balance is mosses and lichens.

The annual primary production was identified only in a few sites of the Arctic:

	g/m^2	t/ha
Northern patchy tundra (Western Taimyr)	37-42	0.37-0.42
Yernik moss tundra (Harp Station)	35-40	0.35-0.42
Shrub-sedge-moss tundras (mid reaches of Pyasina River)	70	0.70
Mountainous tundra (different associations) (Kola Peninsula)	63-321	0.63-3.21
Yernik lichen-moss tundra (Komi, Vorkuta District)	442	4.42
Arctic tundra (estimated data, Rodin and Bazilevich 1965)	-	1.0
Southern tundra (ibid)	-	2.38

The range of fluctuation of annual production values is considerable, and available data are insufficient. It might be noted that annual production in northern and southern tundra subzones differs twice and even three times, while the tundras of the forest tundra zone differ by one order.

The comparison of available Soviet data against the data of other authors shows considerable agreement.

	t/ha
Barrow, Alaska, 71°C N.lat. (Bliss 1962)	0.5-2.24
Umiat, Alaska, 69° N.lat. (Bliss 1956)	0.6
Gratangen, Norway, 68°39" N.lat. (ibid)	0.5
Abisko, Sweden, 68° N.lat. (Pearsall a.Newbould 1957)	2.42
Mountain tundra, USA (Bliss 1956)	0.2-2.08

The data most likely have been obtained by different techniques, and the determinations were made in different seasons of the year, but the results are in the same order of value.

The most important factor which determines the value of primary production is the intensity of photosynthesis. In high latitudes of the Arctic the study of potential intensity of photosynthesis (PPI) was conducted at Vrangel Island by T. B. Gerasimenko (1973) and by Woznesensky et al. 1965 (by the radiometric method). It has been found that at Vrangel Island photosynthesis takes place in a wide temperature range--from -3° to +45°.

Plants were found with high or low photosynthetic intensity in mg CO_2/g dryweight/hour:

High assimilating		Low assimilating	
Caltha arctica	182	*Carex lugens*	66
Rhodiola borealis	132	*Luzula nivalis*	48
Rumex arcticus	121	*Dryas punctata*	33

The PPI range in plants at Vrangel Island is similar to that in the plants at Khibiny and Pamir Mountains (Zalensky 1963).

In the circumstances of the long polar day, plants go on assimilating CO_2 round the clock. The highest PPI values are noted in morning and midday hours. At midnight the assimilation rate may be 25% of the maximum midday PPI.

Large-scale studies for evaluation of forage vegetation in the north have been carried out in the U.S.S.R. V. N. Andreyev (1971) worked out a method of determining green (vegetating) parts of plants which are used for forage (leaves and shoots of grasses and semishrubs). The application of this method combines aerial and surface observations. Tables have been compiled where the wanted value in terms of tons of air-dry mass per hectare is identified on the basis of singling out the contours of definite units of vegetation. From medium-scale geobotanical charts, it is possible to compile a chart of distribution of the stocks of forage resources. More than 60 geobotanists collected a tremendous volume of material using the same method (300,000 points of visual determination and 10,000 hay cuttings). Chamber processing yielded quantitative evaluations of the standing crop and annual production for six zones and subzones of the east European north (fig. 2, 3, 4).

The following regularities have been found: standing crop diminishes from the northern forest zone boundary to the polar ocean coast at a rate of 25 times (from about 12 to 0.5 t/ha), while the annual production dwindles 4.5-fold (from 1.2 to 0.27 t/ha). The volume of annually renewed above-surface standing crop increases gradually from 10% in the subzone of light taiga to 65% in the Arctic semidesert. In addition, other authors worked in tundras

(Abisco, Cape Barrow, Devon Island, etc.) and in mountain (alpine) tundras on high latitude Arctic regions outside the U.S.S.R. Considerable difficulties are encountered in comparing Russian and foreign data: (1) foreign scientists (several critical remarks have to be made here) did not define acurately the type of the biogeocenosis (the ecosystem) and confined themselves to measuring only the production of flowering plants (and, at times, only the sporous plants - mosses and lichens); and (2) annual production was interpreted

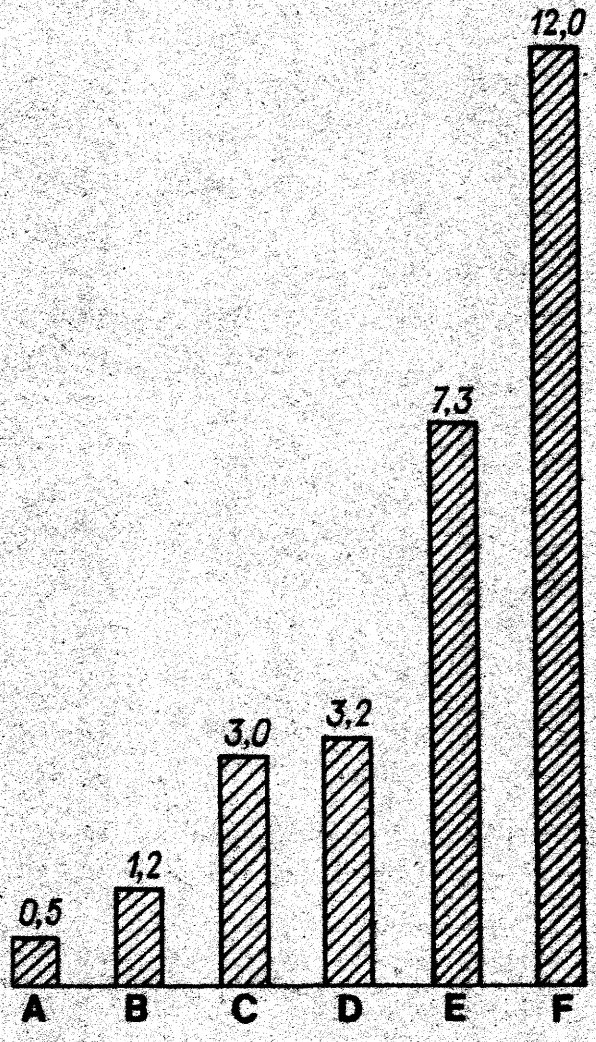

Figure 2.—Surface phytomass by subzone of the eastern European north—T/ha (metric ton per hectare), air dry weight (according to Andreev 1966). A—Arctic semi-desert; B—Arctic tundra; C—Northern tundra; D—Southern tundra; E—Sparse forest tundra; F—Sparse forest.

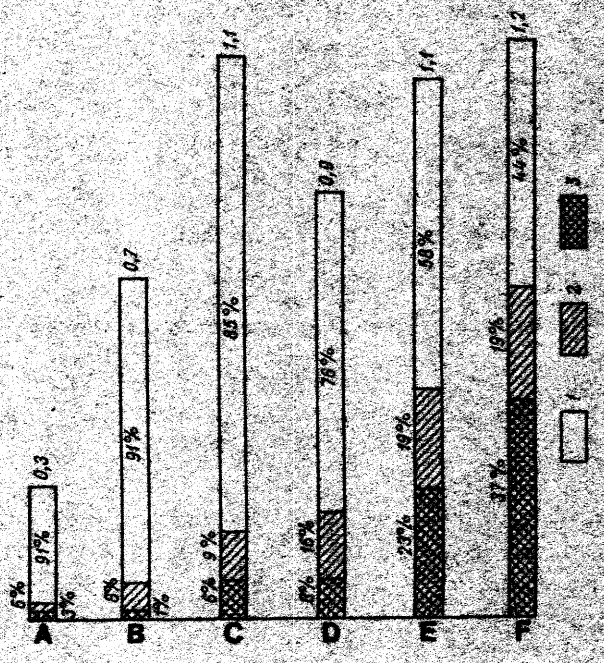

Figure 3.—Annual increase of plant surface parts and its distribution among species of phytomass in subzones of the eastern European north—T/ha, air-dry weight (according to Andreev 1966). 1—annual green organs; 2—perennial green organs, including moss and lichens; 3—wood. A—Arctic semi-desert; B—Arctic tundra; C—Northern tundra; D—Southern tundra; E—Sparse forest tundra; F—Sparse forest.

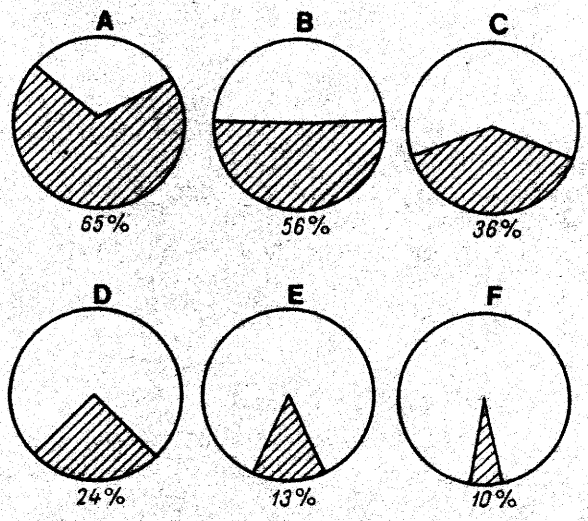

Figure 4.—Annually renewed portion of surface phytomass by subzones of the eastern European north (in %, according to Andreev 1966). A—Arctic semi-desert; B—Arctic tundra; C—Northern tundra: D—Southern tundra; E—Sparse forest tundra; F—Sparse forest.

as the maximum phytomass at the period of its greatest development, which is naturally less than the actual annual production. We shall, nevertheless, present some of the relevant data.

The annual primary production of flowering plants in 1971, g/m^2 (absolute dry weight) on Devon Island, Canada (close to 75° N.lat.) and in Gardangevidde, Norway (60° N.lat.) are as follows:

Tundra types	Surface	Sub-surface	Total	
			g/m^2	t/ha
Spotty northern tundra (Muc 1973)	27.4	70.1	97.5	0.97
Hillocky sedge tundra (Muc)	47.0	191.4	238.4	2.4
Humid sedge meadow (tundra) (Muc)	46.4	160.1	206.5	2.1
Coastal semibrush-sedge tundra (Svoboda 1973)	15.5	4.8	20.3	0.20
Pebbly moss-semibrush tundra (42% rocks) (Bliss and Kerik 1973)	no data	no data	44.1	0.44
Mountainous lichen tundra (Wielqolaski and Kjelvik 1973)	151	111	262.0	2.6

As we compare these latest data obtained in the IBP program against the previously mentioned Soviet and even earlier foreign data (prior to IBP), one can see that they agree with both.

YAKUTSK (CENTRAL TAIGA)

The Yakut stationary establishment, the Institute of Forest and Timber of the Siberian Branch of the U.S.S.R. Academy of Sciences has been in operation since 1955, 28 km north of Yakutsk. The head of the establishment is L. K. Pozdnyakov. Since 1960, another 15 stations were established in all taiga zones and in basins of a number of rivers. I. P. Scherbakov and V. N. Andreyev (1969) reviewed the study and the prospect of utilization of Yakut vegetation. The stations carried out diverse studies of forests on biogeocenological principles. The parameters were determined by establishing permanent study areas. Use was made of conventional inventory using tree models (the technique is described in detail by Pozdnyakov et al. 1969).

As a result of many years of investigation, vast data has been accumulated describing the phytomass of trees. The relevant information has been analyzed, and correlation dependencies have been found between the main valuation indices of tree species and the parameters of individual fractions of the phytomass. Seventeen reference tables have been compiled on their basis, including: crown weight; needle weight; the content of dry substance in wood, leaves and needles of trees, shrubs, and grasses; the weight of roots depending on the weight of the trunk; the weight of generative organs of trees, shrubs and grasses, etc.).

The tables take into account the age of species and their geographical location. Main attention was given to pine forests owing to the increased demand for pine timber and to the fact that pine woods are confined to the valley of rafting rivers.

The following information describes the standing crop of pine forests in central taiga (Pozdnyakov et al. 1969), in t/ha.

Age	Standing			Undergrowth regrowth	Surface cover	Surface phytomass	Roots	Total phytomass
	Timber stock m^3	Trunk and crown	Needles and leaves					
100	115	62.3	3.1	1.79	4.29	71.5	13.7	85.2
140	171	90.9	3.4	3.91	3.21	101.4	23.7	125.1
180	186	99.3	4.0	1.31	3.82	108.4	25.4	133.8

Larch forests prevail on vast expanses of Yakutia. Its productivity is noticeably higher than that of pine forests in the same zone of the central taiga (Pozdnyakov 1975). Thus, the standing crop of larch forests in Central Yakutia is characterized by the following indices (Pozdnyakov et al. 1969) (t/ha).

Age	Standing			Under-brush, re-growth	Surface cover	Above surface phytomass
	Timber stock m^3	Trunk and crown	Needles and leaves			
50	110	53.4	2.2	0.01	0.08	55.7
90	230	140.0	3.4	0.10	0.29	143.7
130	175	107.2	2.1	0.27	1.06	110.6
170	190	117.5	2.0	0.30	1.52	121.3
200	186	118.4	2.1	1.31	2.57	124.4

This book (Pozdnyakov et al. 1969) presents much more detailed information on forest productivity of the entire Yakutiya and Central Siberia by species, zones and districts. Further analysis of the available and future data will make it possible to compile mass tables for a number of biometric indicators similar to the valuation tables available to the forest investigators and practitioners. The application of the tables suggested by Pozdnyakov et al. 1969, helps to considerably reduce empirical measurements and labor-consuming operations related to cutting of model trees, establishment of numerous plots, etc. As a rule, the predictive accuracy of calculating the appropriate values in keeping with these tables within ±10%, which is adequate for practical and for many theoretical objectives.

L. K. Pozdnyakov (1970) notes that there are two interrelated approaches to the study of forest biological productivity (just as of other types of vegetation). The first is the study of biological circulation of matter and the geochemical role of the forest; the second is the study of the forest phytomass from the point of view of identifying the ways of its utilization as timber or as raw material for industry (pulp and paper, chemical, food, and other industries), i.e., the study of its economic productivity.

LAKE BAIKAL

The primary production of Lake Baikal was studied by A. I. Mescheryakova (1975) by the flask technique (Vinberg 1934); this technique provides for calculating the volume of C_{org} in g/m^2. Studies have shown considerable fluctuation of this value from season to season (spring - 50.2, summer - 41.4, autumn - 9.1, winter - 23.7 C_{org}/m^2); from year to year (1966 - 75.1; 1967 - 127.9; 1968 - 187.4 $C_{org}g/m^2$ per year); and in different parts of Lake Baikal (southern Baikal - 131.1; northern Baikal - 119.0; the Barguzin Gulf - 80.2 $C_{org}g/m^2$ per year). Overall these figures vary from 2-fold to 2.2-fold.

On the average, 0.05% of the total solar radiation on the lake surface is utilized annually in southern Baikal districts. The greatest efficiency occurs in August (0.21%), the least in November (0.0002%). Total primary production of Lake Baikal as a whole, comprises 4,000,500 tons C_{org} or 80,010,000 tons of raw algal mass.

Detailed dendrochronological studies have been carried out for many years in Lake Baikal area (Galaziy 1972). This is another method of studying primary production - dendrochronological - was also applied. The analysis included larch and cedar trees, 300-400 years old. Cyclic changes in the growth of timber were found with average duration of 65-70 years beginning with the 13th century; it may be suggested that this value is a multiple of the 33-35-year Brikner cycle of solar activity.

In the climatic aspect, these cycles demonstrate themselves in increased humidity of the atmosphere and an increased water level in Baikal. In recent years we are registering an increase in the annual timber growth rate in Lake Baikal areas.

The possibilities of the dendrochronological technique have by no means been exhausted. Broader and deeper studies of primary production of plants and plant cover will, without fail, lead to new correlations which should make it possible to forecast biological production 3-5 decades in advance (as well as the atmospheric humidity, general thermo-availability, river water capacity, snow cover capacity, etc.). This is of great importance for advance, long-term economic planning (Galaziy 1957).

KURSK

The annual production at the Kursk station was investigated by empirical (cuttings) and estimate techniques based on model trees using growth tables. Annual production of the surface mass in tons per hectare has been determined (Utekhin 1972):

Open steppe areas	2.9 - 4.5
Forest associations	5.3 - 7.1
Barley fields	3.6 - 10.0

Fluctuation of production within the indicated range depends upon humidity, temperature, and the radiation balance. Thus, the stock of standing crop in a meadow steppe on a watershed, at the time of the maximum mowing (after Utekhin et al. 1975) in tons per hectare, was

1969	1970	1971	1972
3.2	2.7	3.1	3.8

Naturally, the annual production varies in the same range. Total annual production of the uncut meadow stock was determined in 1972 after Titlyanova's method (1971). It proved to be:

Above surface phytomass	4.2 t/ha
Subsurface organs	8.4 t/ha
Total	12.6 t/ha

Approximate estimates of complete primary biological production (with consideration for the subsurface mass) indicated that the production of farm crops, even when highly developed farming methods are used, does not exceed total production of natural vegetation. This can be seen clearly from the following data on the production of the surface phytomass calculated by V. D. Utekhin (Gerasimov 1966):

Item	Virgin land	Virgin land with fertilizer	Sowing at experimental station					
			Spring wheat			Barley		
			Grain	Straw	Total	Grain	Straw	Total
Phytomass, t/ha	6.60	9.24	1.61	4.89	6.50	2.27	2.45	4.72
Fodder units/ha	3 300	4 620	2 010	1 090	3 100	2 840	880	3 720

Thus, natural biogeocenoses in the steppe utilize solar radiation and precipitation with greater efficiency for primary production than crops cultivated by highly developed farming techniques at an experimental station. I. P. Gerasimov (1966) believes that this is due to a more complex structure of the virgin land biogeocenosis in the surface and subsurface sphere, which makes possible fuller use of environmental resources (temperature, humidity, soil fertility and other factors). The experiment with fertilized virgin land exceeded the harvest of wheat 1.5-fold and the harvest of barley almost 2-fold. If medium grade farming methods are used on collective-farm soils, the harvest most likely would be one half or one third of that grown in a virgin steppe. Consequently, the potentialities of the cultivated vegetation are not being entirely utilized.

REPETEK

The Repetek Reserve was established in 1912. The studies covered a large program and there are three volumes of the proceedings of the Reserve, and also numerous publications registered in professional bibliographies (Klyushkin et al. 1955, Vejisov and Ishankuliyev 1972). Many aspects of the biosphere have been studied at Repetek and some of them are classical (Dubyansky 1928, Orlov 1928 and other publication of this author, one of the first investigators and directors of the station, Petrov 1933, 1935; Radkevich 1934, Blagoveschensky 1942, Znamensky 1949, and many others). Only a few works, however, were devoted to separate parameters of primary production; for instance, the stock and growth of fuel timber

(Leontiev 1954) and the stock and production of forage mass (Togrzaev 1967). Planned studies of primary production commenced in 1965 with the beginning of the IBP period.

The study of photosynthesis--the physiological and ecological basis of primary production--were carried out by conductometric and radiometric techniques (Voznesensky et al. 1965). It has been found that CO_2 assimilation in most of the desert plants takes place throughout the light hours of the day during the vegetation season (Voznesensky, editor 1975). The following are the relevant data:

Species	Photsynthesis intensity, mg CO_2/gr dry weight per hour		Average photosynthesis productivity, mg CO_2/g dry weight per day	Optimum of observed photosynthesis, °C	Respiration intensity, mg CO_2/g raw weight per hour
	Observed average for vegetation season	Potential			
Ammodendron conollyi	7.6	71	110	22-35	1.2
Haloxylon persicum	6.1	30	55	10-45	1.1

Species	Photsynthesis intensity, mg CO_2/gr dry weight per hour		Average photosynthesis productivity, mg CO_2/g dry weight per day	Optimum of observed photosynthesis, °C	Respiration intensity, mg CO_2/g raw weight per hour
	Observed average for vegetation season	Potential			
H. ammodendron	7.1	40	80	10-30	1.2
Calligonum caput-medusae	5.8	23	80	25	0.7
Ephedra strobilacea	2.3	30	30	5-20	-
Aristida karelinii	21.0	110	250	30-40	1.6
Carex physodes	14.0	65	205	17-30	-

The highest photosynthetic intensities in all plants take place in spring - the most favorable season in the desert. Particularly active are representatives of ephemers and ephemeroids. Low intensities of photosynthesis are characteristic of the species which vegetate for a long time. Plants of Karakumy deserts are capable of assimilating in a wide temperature range from -5° to 55°C. The optimal assimilation temperature for the majority of plants is 25°-30°C.

A remarkable feature of many desert plants is the wide range of optimum temperatures for photosynthesis; *Haloxylon persicum*, for instance, assimilates equally well in a range from 10° to 45°C. The lowest optimal temperature is characteristic for the evergreen *Ephedra strobilacea*, which allows this shrub to continue assimilation even in winter time (on warm days).

As for the daily amount of CO_2 assimilated (photosynthetic production), high capacity is demonstrated by trees and shrubs of long vegetation with a small value of productivity, and grassy plants which vegetate for a short time but have high productivity of photosynthesis. Therefore, considerable primary production of plants with a short vegetation cycle is achieved due to intensive photosynthesis. In plants which vegetate for a long time with low intensity of photosynthesis, however, it is due to the duration of the vegetation period. As a result, the different species of the Karakumy Desert assimilate annually approximately the same volume of CO_2 - close to 15 g CO_2/g per year. Magnitudes of leaf respiration in Karakumy plants are in the range of 0.3 to 1.6 mg/CO_2 per g dry weight per hr. The ceiling for critical respiratory temperature in hot desert plants exceeds values known for temperate zone species and is close to magnitudes for tropical plants. Calculation of the daily balance of substance has shown that in ephemerals respiratory efforts begin to exceed photosynthesis towards the end of their vegetation period; this may, perhaps, be the reason for their death at the beginning of summer.

On the whole, proceeding from the studies at Repetek and in other deserts, it may be concluded that the majority of warm desert plants have certain adaptations which allow them to complete the full development cycle.

Primary production of the associations in the Repetek Reserve has been studied in great detail. The stocks of phytomass of the tree - shrub tier and of the grass cover, as well as the annual production, annual offall, seed production, decomposition of the offall, etc., have been determined. An idea about the stock of above surface phytomass of the main biogeocenosis of the reserve is given by the data of Y. M. Miroshnichenko and R. Togyzaev (1972) (t/ha raw mass):

Biogeocenosis	Number of live plants per ha		Phytomass of live plants, t/ha
	Edificators	Other shrubs	
Haloxylon ammodendron - Suaeda lipskyi	512	81	67.9
Haloxylon ammodendron - Carex physodes	561	193	9.9
H. persicum - Carex physodes	160	48	5.3
H. persicum - Calligonum sp. sp.	146	226	2.9
Eremosparton flacidum - Aristida karelini	60	51	0.2

Thus, the phytomass volume in different biogeocenosis varies by 1 or 2 orders which is completely explained by the sum total of environmental resources in each case. A more detailed study was made of biogeocenoses of *Haloxylon ammodendron* - the most productive in the Repetek Reserve - in which the phytomass and the annual production in the above surface and subsurface sphere of all components-producents were determined (Rodin, editor 1975) (t/ha, air-dry weight):

Species	Phytomass	Annual production	Mortmass	Total organic matter
Haloxylon ammodendron - Carex physodes	26.9	7.5	3.4	30.3
H. ammodendron - Suaeda lipskyi	63.5	16.3	-	-

Thus, the annual primary production of biogeocenosis of *Haloxylon ammodendron* is in the same order of values as the production of steppe vegetation. The main reason for this phenomenon is the high temperature resources, high solar radiation, the length of the vegetation period, and particularly, the successful adaptation to the extreme conditions of life in the desert not only of the edificators, but of all components of biogeocenoses capable of accumulating organic matter at both low and high temperatures. It is found in recent years that a noticeable share in the development of primary production of biogeocenoses of *Haloxylon ammondendron* belongs to mosses and algae, which supply approximately 3% of the annual primary production. This is fully comparable to the volume of surface primary produciton created by grass cover plants. When the

moss cover (*Tortula desertorum*) is very abundant, its annual production may reach 6-9 t/ha (Novichkova-Ivanova 1976).

An outstanding ability of desert associations is the development of vast and powerful root systems. They comprise 60-75% and 70-75%, respectively, of phytomass and annual production in the mentioned biogeocenoses, *Haloxylon ammodendron*. It should also be stressed that in these associations, a few species-edificators play an exceptional role; thus, in the biogeocenosis of *H. ammodendron* - *Carex physodes*, both species produce 83% annual production and even 89% of the volume of ash elements involved by them.

In conclusion of this brief review, the following comparisons of biosphere reserves in the U.S.S.R. are offered:

Territory and type of vegetation	Latitude, °N.lat	Precipitation, mm	Sum of temperatures (>5°C)	Phytomass, t/ha	Annual production t/ha	Production g/m^2/day
Franz Josef Land (Arctic tundra)	72°	500	1200	5.0	1.0	1.7

Territory and type of vegetation	Latitude, °N.lat	Precipitation, mm	Sum of temperatures (>5°C)	Phytomass, t/ha	Annual production t/ha	Production g/m^2/day
Yakutsk (middle taiga)	62°	192	1900	144.0	-	-
Baikal (lake)	53°	-	1600	-	[1]/ 187.4	0.9
Kursk (meadow steppe)	51°	687	2800	23.7	12.6	6.6
Repetek (desert)	38°	114	5600	26.9	7.5	4.0

[1]/ 187.4 is C_{org} g/m^2, not t/ha.

Thus, the biogeocenoses situated in such remote latitudes differ greatly in climatic conditions and, accumulated phytomass. The intensity of primary production, conventionally calculated for the number of days of the vegetation period in g/m^2/day, proved to be noticeably similar. It is natural that the highest intensity in the creation of primary produciton is found in the steppe where environmental conditions are particularly favorable.

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Research on the Higher Vertebrates in Biosphere Reserves

by

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The study of higher vertebrates, in the context of research at biosphere reserves, most likely should be oriented in the following way:

MONITORING THE STATE OF ZOOCENOSES OF REFERENCE ECOSYSTEMS

Monitoring the state of zoocenoses of reference ecosystems should guarantee continuous control of taxonomic and ecological structure of biocenoses and the state of their components. The observation should cover, at least, the size of the populations and the ecological-physiological state of the leading species of the main biological forms. Specific attention should be devoted to declining species. Monitoring animal population levels is a conventional aspect of research at natural reserves. This type of monitoring will probably not present special difficulties. It is more complicated to select the parameters for evaluating the ecological-physiological state of vertebrates. Probably resolution of this question will be facilitated by applying the method of morphological-physiological indicators suggested by S. S. Shvarts. The monitoring of the accumulation in the organisms of vertebrates of chemical substances--industrial waste and pesticides--and their migration along the alimentary chain is indispensable. It is likewise expedient to arrange monitoring of animal behavior and the development of synanthropisation.

The collected material should be published once every 3 to 5 years and circulated, on an exchange basis, to all biosphere reserves and to other concerned establishments. This would facilitate comprehensive global analysis of animal populations.

AUTECOLOGICAL STUDIES

It is natural that the preservation of zoocenoses in reference ecosystems, the study of their ecological structure and functioning, just as the monitoring of their state, should have a fundamental autecological basis. Therefore, studies at biosphere reserves should include the distribution of individual species of mammals and birds, habitat peculiarities, phenology, migration, nutrition, breeding and mortality, age and sexual structure, behavior, seasonal and multi-year dynamics of the number of populations and

the influence of natural and anthropogenic habitat factors upon all these processes.

Zoologists face a great deal of work covering all the mentioned areas of research which will be conducted concurrently at all biosphere reserves. The latter circumstance taken together with the standardization of research methods will guarantee complete comparability of all findings. Therefore, it is necessary to determine the appropriate staff composition of research and scientific-supporting personnel at reserves, identify other scientific establishments in the light of their possible involvement, and draw up the list of research priorities.

STUDY OF BIRDS AND MAMMALS IN ECOSYSTEMS

The Paris Conference on the Biosphere concluded that a synthetic and analytical study of ecosystems was necessary. This requires examining the ecological structure of mammals and birds and their involvement in the transformation of matter and energy.

The ecological structure of the vertebrate population should be understood as the relationship and spatial distribution of the number and of the biomass of groups of species with a similar mode of life. Most likely, to appreciate the extent of this similarity, one needs to operate with an ecological classification of animals. The efforts at developing this classification began at the turn of the century. These efforts produced the concepts of "adaptive types" and "bioforms" and "Ecological Equivalents." At present, it is advisable to draw a wide range of biologists into the elaboration of the ecological classification. This classification should cover all animals of the planet; and in conformity with the tasks of biosphere reserves, it should differentiate mammals and birds by the specific features of their relations to the habitat. The latter requirement makes it expedient to build this type of classification on the basis of ecological criteria suggested by A. N. Formozov. Formozov divides animals into biological forms which are associated into biological classes. The characterisitics of biological classes are the trophic relationships of species and the tier of the biogeocenotic cover which is occupied by them; the characterisitics of biological forms are the modes of procuring food, peculiarities of motion, construction of shelters, and adaptation to unfavorable seasons of the year. The similarity of relations with the habitat within one biological form predetermines the similarity of their responses to changes in the conditions of existence and the simlarity of participation in the biological circulation. Therefore, the biological forms of Formozov are functional units of the zoocenoses structure. A classification built on this foundation will render easier the comparative analysis of the structure and functioning of ecosystems of different zoogeographical regions and districts.

Two forms of participation of vertebrate animals in the biological circulation are distinguished in the U.S.S.R. One of them is in the transformation of matter and energy on the separate trophic

levels. This form has had considerable attention in the International Biosphere Program. The research launched by that program apparently should be continued. Its place in the work of biosphere reserves, however, will become clear only after a thorough analysis of accumulated data.

The second form of participation of vertebrate animals in the biological circulation is determined by their influence upon the functioning of other components of the ecosystem. This influence requires further study. The available findings, however, prove its importance in natural processes.

The approved program of biogeocenotic studies in the U.S.S.R. (1974) provides for a quantitative characterization of the participation of vertebrate animals in the formation of the atmosphere's gas composition and in water distribution--the formation of the surface runoff, the distribution of moisture in soil, the formation of the hydrothermal regimen of the close-to-the-surface layer of air, the progress of water and wind erosion, organic and mineral additions to the soil substances and their conversion and mixing in the soil profile, the influence of animals on the growth and development of vegetation, and the elucidation of the role of all these processes in the formation of primary production in the autotrophic cycle of the biological circulation. The study of the mentioned questions should be conducted at biosphere reserves as well. Only in this case is it possible to receive a sufficiently full characterization of the way the reference ecosystems function.

To resolve biosphere problems it is necessary to have a clear-cut idea of how natural ecosystem functions will be altered by man's economic activity. The latter circumstance will uncover the mechanism of anthropogenic peculiarities of the biological circulation which are decisive for the evolution and the destinies of the earth's biogeocenotic cover. In this connection, it is expedient to investigate the taxonomic and the ecological structure of zoocenoses and the extent of participation of animals in the biological circulation of pasture, agricultural, forest, and commercial and recreational ecosystems. Notwithstanding the fact that this work transgresses far beyond the confines of the conventional themes of study at reserves, its implementation should be vested with the staffs of biosphere reserves. This will guarantee the comparable, ecological approach to the examination of parent and derivative associations and the uniformity of the applied research techniques.

CONSERVATION OF REFERENCE ZOOCENOSES

At present, practically all biocenoses of the world have been altered by man in greater or smaller degree. It is therefore necessary to identify the degree to which taxonomic and ecological structures of the animal populations in biosphere reserves retain their parent features. The answer to this question is indispensable for a proper characteristic of the territories protected as reference models of nature. The answer to this question demands

large-scale studies of historical ecology at biosphere reserves. In some cases, the results of these studies will make it possible to commence the restoration of parent zoocenoses by reacclimatization of exterminated animals. A well-known instance of this type of reacclimatization might be the successful experiments of settling the beaver, the sable and the auroch in Soviet reserves.

The restoration of the natural structure of zoocenoses might prove impractical without reinstating original plant associations on the territory of the reserve.

The restoration of original zoocenoses requires great caution and is permissible only when based upon an adequate natural-historical foundation. Properly implemented, it will increase the reference significance of the protected ecosystems and facilitate conservation of the genebank of animals and plants and preservation of rare and disappearing species. The specific features of the economy and the mode of life of the population in the districts of biosphere reserves and some other causes, many of which cannot be forseen, might render complete reinstatement of the original zoocenoses impractical or even impossible. It is necessary to provide a system of biotechnical measures supplementing the functions of exterminated animals in such reserve ecosystems. Past experiences have proved that without such measures the development of associations under protection begins to contradict the main goals of reserves' regimens. Abandonment of these tasks may cause the emergence of peculiar ecosystems which have nothing in common with the real reference models of nature. Questions on the possibilities of restoring natural structures and applying biotechnical measures in biosphere reserves have many debatable aspects and merit special consideration.

The conservation of reference systems will be greatly complicated by anthropogenic pressure upon zoocenoses from territories adjacent to biosphere reserves. In the small size we know that reserves in the European part of the U.S.S.R. regularly accumulate ungulates from neighboring districts where they are harrassed by hunters and lumberjacks. The excessive population densities of the animal population that results lead to zoogenic successions of the plant cover. Similar facts have led to a conclusion that the reserve territory does not ensure the regulation of the surrounding associations, and the changes in the latter predetermine changes in the protected ecosystems. K. D. Zykov and collaborators, who have formulated this thesis, suggest that it be taken into consideration when determining the area and the shape of the reserve territory. Owing to historical, social, and economic reasons, however, it is not always possible to take guidance from these recommendations. Therefore, to preserve the reference ecosystems, one has to elaborate a system of special measures protecting the biosphere reserves from anthropogenic processes which are developing on the surrounding territories.

Soil-Zoological Studies of Biosphere Research Stations

by

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Soil animals are an important component of the biosphere. They account for the bulk of the zoomass. If one judges by quantitative indicators (by the volume of transformed energy in particular) soil animals are approximately equivalent to another important member of the heterotrophic complex--saprophilous soil microflora. A close functional relationship has been recorded between these links of heterotrophs: animals are a powerful factor which invigorate microflora activity. The most characteristic and essential components of the animal soil population are saprophages which account for the bulk of the zoomass in all humid landscapes. The saprophilous complex of invertebrates is engaged in mineralization of the decaying organic matter and plays a tremendous biogeocenotic role. The latter consists of the immediate biochemical and physical influence on decaying organic matter and in stimulating the activity of saprophytes. Thus, soil animals, together with the microflora, create the foundation for the basic processes which are decisive for the functioning of the biosphere. Therefore, soil-zoological data are of primary importance in the research into general regularities of the structure and functioning of the biosphere. Extensive data about the role of soil animals in biomes of different climatic belts and zones have been obtained as part of the International Biological Program and summarized in relevant publications (Ghilarov and Chernov 1974, 1975).

Extensive soil-zoological studies have been carried out in the U.S.S.R. They characterize the structure and the biogeocenotic role of the animal soil populations in different zones and altitudinal belts. General regularites of the zonal and regional distribution of the biomass of soil animals have been revealed, as well as the changes in the trophic structure and their biocenotic role. There are numerous data describing the biogeocenotic activity of various groups of soil fauna, the regularities of their territorial distribution, and participation in different types of ecosystems. Methods of integrated, quantitative study of the soil animal populations have been developed, including techniques of experimental determination, estimation, and analysis of different synecological indicators, applicable to the animal population of soils (Techniques of Soil-Zoological Studies, 1975).

In the context of the "Man and Biosphere" Program, experts in soil zoology are facing new tasks. First, they should process the accumulated data to determine the most general global regularities in the participation of soil animals in the functioning of the biosphere. Second, they should increase research into the structure of ecosystems and the trophic-energy processes in the most typical and economically important types of zonal biomes, paying particular attention to anthropogenic influences on the living cover of the Earth.

Changes in original natural communities under anthropogenic influence, are becoming more pronounced. The number of places where the original, natural soils have been preserved is shrinking rapidly throughout the world. Meanwhile, knowledge of the specific features of the organization of original cenoses is indispensable for developing a general strategy of man-biosphere relationship--for the development of a system of measures for maintaining soil fertility, in particular.

The importance and relevance of the study of soil fauna is, therefore, perfectly clear. One should bear in mind the tremendous direct role of soil animals in the functioning of ecosystems and also the possibility of utilizing them for identifying the character and trends of changes in soils, vegetation, the chemical peculiarities of environment, and radioactive contamination (Ghilarov and Krivolutsky 1971). The main principles for using soil animals for identification purposes have been worked out as a general theory of soil diagnostics, based on zoological information (Ghilarov 1965). The task of applying these principles on a larger scale stems from studying the biosphere as a whole.

To answer all these questions, we must initiate permanent studies at stations in the most typical zonal landscapes of different belts and zones, where the most characteristic types of soil can be singled out and used as reference types. The information obtained at these permanent monitoring sites should be used for extrapolation to larger territories.

The system of soil-zoological research at permanent monitoring sites should, to the greatest possible extent, reflect the biosphere's zonal, altitudinal, and regional differentiation. The study areas should be distributed in a way to cover territories with both the optimal and poor combinations of environmental factors for the production processes. First, it is necessary to undertake detailed studies of the structure of the animal soil population and of its geochemical activity in areas with highest biological productivity and a high intensity of biogeocenotic processes. In the temperate belt, this would concern primarily the forest-steppe districts with chernozem soils and broadleaved forests on grey soils. Particularly favorable for integrated synecological studies is the territory of the V. V. Alekhin Central-Chernozem Reserve and parts of the Tula Region. Soil-zoological studies in forest-steppe landscapes and in broad-leaved forests are essential for discovering many fundamental factors of soil animal participation in the production processes

and in the circulation of matter. Soil fauna of the chernozem steppe is extremely rich and varied ecologically (Ghilarov 1960, Chernov et al. 1967, Chernov 1975). This is where the direct animal influence on the soil profile is particularly deep and the zoomass is very high. Characteristic of the area is a high differentiation of the trophic composition (besides the saprophages, there are numerous soil phytophages, predators, and omnivorous forms). This is due to the fact that the forest-steppe is situated in an area particularly favorable for production processes, owing to a balanced hydrothermal regimen (the radiation index of dryness is near to 1). Owing to this, the forest-steppe landscape should be taken as a starting point for the global zonal analyses of the animal soil population. The quantitative characteristics of other biomes should be compared against them.

To determine the complete structure and dynamics of the animal population of soils, research should be undertaken in broadleaved forests. The soil fauna of the broadleaved forests has slightly less taxonomic and ecological diversity than that of the forest-steppe. The biomass, however, is greater here, reaching 2 tons/ha. This is due to the abundance of large-size saprophages and particularly--the earthworms.

Particularly promising, in the oak woods, are the studies of general regularities of the functioning of the saprotrophic link of biogeocenoses, the processes of utilizing and incorporating plant remains into the circulation. Oak groves to the south of Moscow and in the Tula vicinity may be used as reference territories.

A comparison of landscapes with optimal and poor climatic conditions for production processes is of considerable importance for the understanding of general regularities in the zonal structure of the animal soil population. An increase in dryness results in a sharp decrease in the number of the main links of soil fauna--the saprophilous complex; there is an increase, however, in the specific share of soil phytophages, which play a considerable role as farm pests. The animal soil population acquires many basically different features. Studies in clay, semidesert, and desert areas are indispensable for determining the typical peculiarities of the structure of the animal soil population in arid landscapes. The semidesert territory near Djanybek is particularly suitable for setting up a semidesert station for biosphere research. This territory has a Reserve which belongs to the Forest Studies Laboratory of the U.S.S.R. Academy of Sciences. Particularly interesting in semidesert conditions is the integrated character of the soil cover--the combination of several types of soils on a small area (solonets, chestnut, chernozem-like). This demonstrates the specific features of the boundary zone between desert and steppe area. The soil fauna as a sensitive indicator of the geochemical regimens reflects the integrated character of the soil-plant cover. The importance of studying the soil fauna in arid landscapes is related to the problem of aforestation. Communities of soil organisms may serve as a sensitive indicator of geochemical shift during irrigation, melioration of salted soils, etc.

Studies in the desert zone should be conducted at least at two permanent monitoring sites: in clay deserts (particularly indicative are the landscapes of Usturt Plateau) and in sandy deserts near Repetek, for instance. The comparison of the soil fauna of sandy and clay deserts can provide much material for answering fundamental questions about the origin of deserts, the regularities of lasting anthropogenic changes in arid landscapes, and also for the elaboration of measures for economic use of soils in arid areas.

North of the forest-steppe ecotone are the humid landscapes where the share of saprophages in the soil fauna increases, while the share of phytophages decreases. The activity of soil invertebrates as agricultural pests goes down in the boreal regions. The animal life in soil and litter in forests plays a considerable role in mineralization and humification of vegetative remains and in drawing them into the biological circulation. It is necessary to establish several stations for research into the soil fauna of taiga forests in the European part of the U.S.S.R. and in western and eastern Siberia. It is particularly important to select sites where it is possible to trace all successional stages leading to mature climax forest stands. The districts where postintensive cuttings are located are favorable for this type of research.

Soil-zoological studies in the Subarctic are of fundamental interest. The general impoverishment of the qualitative composition of the animal world--the simplification of its numerical and trophic structure--makes it possible to conduct frontal examinations of a large number of pedobiont groups. In other words, it is comparatively easy to obtain total quantitative characteristics of communities. This is particularly important for the elaboration of general principles of integrated study of the living cover of the world as an entity. The districts of Taimyr are particularly suitable as reference territories for integrated studies of soil fauna in the tundra since all three tundra subzones are well expressed there--southern, typical, and Arctic tundras. First of all, a study should be made of the typical tundra landscapes which represent the most characteristic peculiarities of Subarctic regimens.

For a clear idea on general patterns of the animal soil populations, we should have information on extreme landscapes--such as polar deserts on Arctic islands. Against a background of considerable impoverishment of the taxonomic composition of the animal world as a whole, the animal life in the surface layer of barren rocks with lichen-algae communities on Arctic islands is most peculiar and relatively rich in number. The population density of *Nematoda*, *Collembola* and enchytraeids in polar deserts is so high that the total zoomass reaches values which are characteristic for much more southern biomes (in some places 10, at times 20 g/m^2). It has been found that the zoomass-phytomass ratio reaches its maximum in polar deserts, which indicates the great part played by the animal soil populations in the total production processes.

Many methodological principles should be followed when studying soil fauna as a component of the biosphere. In particular, it is necessary to take duplicate quantitative censuses of as many groups of invertebrates as possible, using comparable techniques which indicate density per unit of area. This allows estimation of total values which illustrate the role of soil animals in the circulation of matter in communities of different structure. First of all, it is necessary to estimate the total biomass, total metabolism, annual production, etc. It is essential to make a separate count of functional groups which is indispensable for the analysis of the trophic-energy structure of communities.

The quantitative characteristics of the animal population of soil should be strictly related to the structure of landscape; in particular to the peculiarities of the drainage-geochemical processes (Stebayev 1976). Thus, a clear-cut distinction should be made between zonal and intrazonal parts of the landscape and of the corresponding types of communities. The relation of zonal and intrazonal soil types and of their animal population changes in a regular manner in different zones. Under poor conditions (arid and nival) we see a great contrast between soils and animal populations in watershed areas and in the intrazonal biogeocenoses. Here the production of intrazonal communities is the highest in a given type of climate. Thus, in the Subarctic, in nival meadows on slopes, the zoomass reaches the same level as in the chernozem meadow steppe (up to 50 g/m^2) whereas in tundras, no more than 10 g/m^2. Therefore, precisely these elements of the landscape, which usually cover a small part of the territory, are of the greatest interest in evaluating the production-energy potential of biosphere components.

Experience has shown soil animals to be one of the last representatives of the animal population in an environment altered by man. Their communities maintain considerable variety of species and number even in islands of natural vegetation, such as municipal parks and botanical gardens (if these areas are not trampled out by people). For this reason, soil animal research at permanent biosphere stations near large cities, or in areas extensively developed by man, is of particular interest; it may provide us with the most complete information concerning the condition of the animal population and its changes due to anthropogenic influence.

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Entomological Studies in Biosphere Reserves

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The study of insects is a major aspect of present-day integrated biogeocenological studies including those in future biosphere reserves. The program, the methodology, and expected results of entomological studies in biosphere reserves are determined by the features and importance of areas singled out as reference territories. The first stage of research is to discover the composition of insect species in the studied territory. Such data can often be obtained rather quickly by analyzing previous studies, not necessarily on the territory of the reserve, but in the same zoogeographical province. As a rule, such data are available; nevertheless, some "blank spots" will definitely be encountered in poorly studied areas. Thus, the primary task in the studies covering biosphere reserves will be to study faunistic material in the given territory and to fill in the existing gaps in particular groups of insects by means of specific studies.

The initial phase should include the establishment of collections and ensuring the necessary and proper long-term maintenance of them in the reserves. This type of a collection need not be a large one. We have in mind a reference bank for the preliminary rapid identification of the most important species directly in the field. Special attention should be given to the species which are specific for the region where the biosphere reserve is established.

The second phase is research into fundamental biology of some species in key plots: i.e., their life cycles, nutrition, habitats, role of predators and parasites, etc. Priority should be given to the most abundant species of primary importance for the functioning of the ecosystem, and to those species inflicting harm on man, as well as on species of peculiar zoogeographic and phylogenetic interest, or endangered and therefore protected species. There is usually a rather small number of such forms among insects, although further study might increase the recognized number.

In the first two stages, the administration of biosphere reserves should be able to invite leading specialists from outside (while not having them in the staff) and coordinate these studies within the total research program.

The collection of faunistic material and initial data on the biology of insects will create conditions for more multidisciplinary studies of ecosystem dynamics which are the basic research task of biosphere reserves. Basic trends of research in ecosystem dynamics will include: (1) the study of the population dynamics of important species, (2) the study of entomoconsortiums (or, together with other specialists, consortiums as a whole), (3) the study of succession processes in individual components of an ecosystem, etc.

The study of population dynamics of important insect species is labor-consuming and requires adequate equipment and highly trained researchers.

These studies will be effective if preceded by preliminary work which makes it possible to select the proper objects and to coordinate the research methods with specialists studying other aspects of similar objects.

The study of insects as components of basic consortiums is very promising. It is sometimes possible to single out one species or a limited number of plant species in an ecosystem and to study thoroughly the insects related to these plants. When entomological studies are conducted in comparatively uncomplicated phytocenoses, characteristics of insects which belong to several leading consortiums make it possible to contribute to the study of the fauna, biology, and the structure of associations.

One of the most important fields of study in biosphere reserves is a thorough analysis of consortiums including the inhabitants of the rhizosphere, i.e., the soil insects.

Besides the consortiums, the biogeocenosis incorporates other points of animal concentration. First, there are the decaying plant and animal remains: Wood, fungi, decomposing leaf litter, animal carcasses, etc. In some cases, the animal associations which are formed as a result of this type of accumulation of organics, specifically if their decomposition has been on for a long period, are very complicated and subjected to regular changes in time (succession). The study of these successions is important; without it, it is difficult to understand the peculiarities of the circulation of matter.

Taxonomic and ecological diversity of insects is many times larger than the diversity of plants and higher animals. The tasks of entomological studies in the biosphere reserves are not independent but subordinated to the overall program of research into bioenergetics of the ecosystem. The analysis of the entomocomplex is in many cases determined by the preceding analysis of phytocenosis. In many cases, it is necessary to depart from species and genus level of study, and to analyse the entomofauna by its role in the ecosystem based on trophic groups--for instance, soilformers, saprophages, xylophages, foliage consumers, etc. It is expedient to conduct an integrated study of insects-saprophages and saprophytic fungi to obtain a quantitative

appraisal of energy transformation. These integral conclusions are based, naturally, on the summation of the results of the earlier-mentioned phases of research.

Consequently, the study of insects on three consistent levels--faunistic, biological, and synecological--will make it possible to determine their importance in the functioning of reference ecosystems.

Of the numerous possibilities of illustrating the aforementioned fundamental tenets relating to entomological studies in biosphere reserves, it seems to be more advisable to consider the experience of organizing permanent studies in arid zones (including saksaul[1/] forests) and the study of the ecology of xylophilic associations in forest zones. Since 1970 the Joint Soviet-Mongolian Biological Expedition has been conducting an in-depth biogeocenological study of entomocomplexes in the main natural zones of the Mongolian Peoples Republic--the mountain-forest-steppe, the dry steppe, and the desert-steppe at three stations: on the eastern slope of the Hangai Mountain system, in Central Mongolian steppes, and in the Gobi Desert. The studies are sponsored by the Institute of Biology of the Academy of Science of the Mongolian Peoples Republic, and the Institute of Evolutionary Animal Morphology and Ecology, U.S.S.R. Academy of Sciences.

The aim of these studies is to describe the entomocomplexes of the main natural zones of the Mongolian Peoples Republic in biogeocenological terms--to determine the composition and the structure of populations, establish its relationships with other natural factors, and appraise the place and importance of insects in biogeocenoses. Studies of this type are being conducted in central Asia for the first time, although some previous experience accumulated in the past decade during the work in Central Kazakhstan.

The following main questions have been studied for 5 years: (1) the general faunistic composition of each station as a whole. For the main types of biogeocenosis (stationary sections) it helped to determine the distribution of insects and the basic components of every association; (2) the general number of insects and their dynamics which help to determine the dominants and appraise their role in each association; (3) the phenology of life cycles determined by specific continental and arid conditions in central Asia; (4) description of the preimaginal phases of dominants; (5) the consortive relationships of insects and the extent of damage caused to the main species of plants; (6) the determination of bioforms (pedobias, herpetobias, phytobias, aerobias) and their respective participation in biogeocenoses and distribution of the entomofauna in biohorizons; (7) the relationship of the main trophic groups (phytophages, saprophages, predators); (8) the general appraisal of the insect biomass and its influence upon biogeocenosis; (9) the economic importance of the prevailing species, etc.

[1/] Saksaul is *Haloxylon* throughout this article.

In conjunction with the detailed study of associations in key plots, important supplementary data can be obtained through less-detailed studies on the linear profile which also covers secondary biocenoses. This profile can range from 10-15 to 70-80 km. A combination of data covering the profile and the key plots makes it possible to describe the entomocomplexes of a large natural area in an integrated manner.

Studies have indicated sharp distinctions in the group composition and in the zoogeographical structure of each zone. Even within one zone, it was found that different types of biogeocenoses differ sharply in genesis. Many insects proved to be important edificators of individual associations, subzones and zones. Thus, leaf beetles play an exceptionally important role in identifying the boundaries of desert steppes, on the one hand, and of plains and mountains on the other. The most typical arid herpetobionts, which lack narrow trophic specialization and are, therefore, practically independent of the type of plant association, can be much more sensitive indicators of abiotic factors and of the biogeocenoses as a whole than the vegetative associations. Thus, a regular substitution of certain types of insects by others has been observed in a vertical profile of the desert-steppe station in a range of 1 000 to 2 000 m above sea level and on a length of 72 km. The zone of spread of each species is quite insignificant (up to 4-5 km) which corresponds to a change in the altitude of several tens of meters. This concerns primarily the darkling beetles, the most clearcut edificators of lower rank associations in the arid zone.

Sharply mosaic spread of insects related to individual large groups of plants has been found in all arid associations. This feature immediately identifies the body of plants whose consortive relationships are to be identified. The African millet (caragana), wormwood, Nitraria, and saksaul proved to be the fauna concentrates in the Gobi. Approximately 70 species of insects were identified for saksaul. It was also shown that the entomocomplexes of middle Asian deserts differ greatly from the central Asian deserts both by composition and structure of the population and by the absence of spring ephemers in the sharply continental conditions of middle Asia.

The entomocenoses of saksaul forest were studied by the associates of the Institute of Evolutionary Morphology and Animal Ecology in the Karakum Desert in 1970-1971.

After analyzing all literature on the fauna and ecology of the saksaul forest insects, the dominant species--saksaul--was taken as the basis for the study of the consortium.

Using the technique of entomological net sweeping in saksaul crowns, we have registered representatives of 10 families (outside of the specifically studied groups) in the spring. The special study of gall-producing insects as pests of saksaul made it possible to identify 32 species of this group and to suggest that gall-producing insects consume up to 10% of the energy resources the plant expends on vegetation. As in other basic groups of

saksaul forests, a special study was made of the Orthoptera insects, represented by five orders and ants. In particular, 16 ant species were subdivided into trophic groups; the number of their nests per 1 ha was determined, as well as the intensity of feeding and the importance of ant species in the biogeocenosis of the saksaul forest.

Special attention was given to soil insects which were studied by soil sampling on an area of 50 x 50 cm and additionally--by direct investigation of the insects of the plant rhizosystem. The biology of 35 species of insects which develop in plant roots was studied. A special program was set up to study the characteristics and significance of a "background" species, the large Caspian termite.

As a result, the faunistic and biological stages of research, and to some extent the synecological stage, were carried out in the reference saksaul forest.

The entomocenoses of temperate forests are considerably richer than those of saksaul forests. Accordingly, one can encounter much more difficult problems there.

The consortive approach to the study of entomocomplexes requires a similar study of the entomoconsortium of dominant arborous species--as was done in the saksaul forest. If insects associated with coniferous trees are studied in a coniferous forest, and those associated with the birch are studied in a birch forest, etc., we can hope to make a fundamental contribution to the study of the major links of the appropriate forest entomocenosis. Afterwards, it can be extended to the study of secondary links.

There are, however, specialized groups of insects in humid forests which need to be separately studied. These include, in particular, insects which destroy dead wood. As the result of long-term study in the Palearctic, it has been possible to trace a 5-stage succession of complexes of xylophilic insects. For every stage, species composition for the inhabitants of the bark and of the wood proper was separately ascertained. The trophic relationships of insects have also been described. The approximate significance of individual groups of xylophages as wood destroyers was also determined. The zoogeographical aspect of the formation of xylophilic entomocomplexes has been studied. The results referred to the Far East have been partially published.

In whatever part of the forest zone a biosphere reserve is established, its research program should include the study of such diversified associations of insects as those inhabiting wood.

In conclusion, it should again be emphasized that successful study of the entomofauna of biosphere reserves will permit us, on the one hand, to define the degree of anthropogenic influence on the entomocenosis as an integral part of biocenosis; on the other hand, we will be able to indicate possible protective measures for the respective entomocenoses and individual species.

Hydrobiological Studies in Biosphere Reserves

by

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GENERAL CONCEPTS

Though nature conservation is an extremely difficult undertaking, a few simple truths should be pointed out. First of all it is evident that natural biological systems are shrinking in size and are being destroyed. Hence the necessity of identifying these changes with the idea of preventing them.

Further on, it should also be noted that the unwanted biological consequences of damage to environment are alarming. Therefore, the priority should be given to monitoring biological systems using biological indicators and those of the abiotic factors which control the biological processes or which cause unfavorable changes in them.

The monitoring program in biosphere reserves should provide for an inventory of the species composition, the structure and functioning of terrestrial, soil, and aquatic biological systems. Further on, we shall consider the monitoring of inland water biological systems.

Lakes, with their population, comprise native centers of natural complexes since they receive dissolved and suspended materials with the discharge from their water basin. L. L. Rossolimo (1975) drew attention again to the fact that the lake, as an accumulation system, is a source of information about the changes occurring in its water basin. Therefore, it seems that lake associations represent a significant object for monitoring the state of the environment and the damage caused to it.

Information is necessary on the composition of lacustrine population and the structure and functioning of communities in an undisturbed environment. Monitoring of a standard list of biological indicators should be conducted for many years. Hence, the necessity of having inland water reservoirs in every biosphere reserve for hydrobiological monitoring.

Part of this work consists of summarizing the available scientific information. A number of institutions in the U.S.S.R. have also accumulated this type of information. Among them: the Institute of Biology of Inland Waters and the Institute of Lake Studies of the U.S.S.R. Academy of Sciences, the Institute of

Hydrobiology of the Ukrainian Academy of Sciences, the Institute of Limnology of the Siberian Branch of the U.S.S.R. Academy of Sciences, the Institute of Biology and Geography of the Irkutsk University, and others (Zhadin and Gerd 1961, Kozhov 1962, Rybinsk reservoir 1972, Tseeb and Maistrenko 1972, etc.). Among completed programs we may note the extensive research which elucidated regularities related to the formation of the population of new reservoirs (the Institute of the Biology of Inland Waters, U.S.S.R. Academy of Sciences).

It is necessary to get an idea of the normal and disrupted level of the monitored characteristics.

Monitoring of lake organisms may be carried out on the following levels:

1. Communities--species composition, structure, and functional indices. Most likely the functional summarized characteristics of communities cannot be regarded as indices which describe their state well. Plankton can serve a swiftly responding and methodologically convenient communities.

2. Populations--quantitative dynamics in unaltered and altered environments.

3. Indicator species.

4. Physiological level (Larkin and Northcote 1969, Frey 1969, Smirnova 1962, 1968, and 1974).

5. Molecular level--the determination of the state of environment by metabolic links which are vulnerable to toxicants and other similar influences.

6. Special monitoring of mutagenic, teratogenic, carcinogenic influences.

7. Registration of abiotic environmental factors.

8. Registration of the natural cycles of biologically active substances.

ZOOPLANKTON

Zooplankton form convenient communities for monitoring the state of environment. Unlike phytoplankton, zooplankton are less dependent on regular changes of chemical factors of the environment and reflect more durable and larger changes. The latter may be a result either of the natural development of lake communities or of man's intervention in the life of a given lake and the discharge of water into it or into the surrounding landscape. It has been found that lakes which are withdrawn from strong economic influence retain the character of their plankton community for dozens of years.

There is information stating that the species composition and the quantitative indices of zooplankton are stable for periods ranging from 16 to 26 years (Smirnov 1973).

Also known are changes in the dominance of particular species. Thus, the maximum number of *Daphnia longispina* in Upper Boden Lake in 1952-1962 increased more than five-fold compared to 1932-1935; the survival of some of the females in plankton continued up to February whereas earlier they used to disappear in August (Elster and Schwoebel 1970). The domination of *Daphnia* in 1949 in Lake Cuteney (British Columbia) was replaced by the prevalence of *Diaphanosoma* in 1969 (Zyblut 1970). Intervention into biological relations in a lake by way of introducing new species of fish resulted in a decrease in the crustacean plankton, extraordinary numbers of some species, and greater seasonal fluctuations (peaks) of species. Thus, 6 years of observation at Snuff Lake in Canada revealed an unusual peak of *Chydorus sphaericus* (Anderson 1972). Planktonic crustaceans, which were destroyed by a single introduction of 0.75 mg/l of rotenone, were restored in 3 years (Alberta, Canada; Anderson 1970). Zooplankton, however, failed to be restored for 6 years in Paul Lake (British Columbia, Canada) after it was suppressed by 0.004 mg/l of toxaphene (Larkin et al. 1970).

Brooks (1969) emphasizes that the influence of pollution upon zooplankton may be a result of several developments, since a dislocation of the environment may influence many links of the biological system - from algae to fish.

INVENTORY OF THE SPECIES COMPOSITION OF FAUNA AND FLORA

The inventory of the main components of biological systems - species - is necessary to determine the biological processes in these systems and the changes in the sytems. This, however, is a difficult task which in most cases cannot be settled even at sites of stationary monitoring. B. A. Tihomirov (1971) stated that the inventory of species is a matter of high priority and necessity in biocenological studies. The difficulties involved in the task were even noted in the literature. Thus, R. Dajoz (1975) noted: ". . . from the practical point of view the study of all components of a biocenosis is next to impossible and was never undertaken, since it involves the extremely difficult problem of identifying all the species which exist in it. More often, one or several well-known groups represented by different, rather numerous and ecologically diversified species are studied."

Water biologists and geobotanists also seek complete inventory of the species composition which is limited by practical difficulties only. It is a difficult task to determine the number of species in a biological system. The number of recorded species in limited areas, like lakes and in artificial reservoirs with an altered natural environment, is about 2,000 (according to prolonged or stationary monitoring, not counting the species of bacteria). Single examinations almost always give an incomplete list which is due to seasonal changes in the number of species. The accuracy of

data given in literature in many cases is directly proportional to the amount of effort, rather than to the real number of species.

It is also noteworthy that in the average living conditions, the number of species within an association is not great. They are interrelated by strong or weak, positive and negative relations. The large number of species in itself creates the possibility of a variety of solutions in definite biological situations. According to B. A. Tikhomirov (1971): "The species abundance in a definite area is an indicator of life activity, self-regulation and of a relative stability of the biogeocenosis."

The number of species is small when some factors of the environment reach extreme levels. In connection with this, extremely salty reservoirs and thermal springs represent the few situations for which the number of species has been accurately determined, since the number itself is small.

Owing to the unfeasibility of a complete inventory of species composition for the appraisal of the state of the environment, we should draw up a list of standard groups of species which are related taxonomically (taxocenoses) for whose inventory we can provide an adequate number of specialists. These groups should include, for instance, insects, crustaceans, and diatomic algae.

The list of species of this cenosis might include mass species which can be found annually as well as rare species which are not found every year. For instance, the cladoceran *Ophryoxus*, which has been recorded in the Rybinsk reservoir, is not annually found; but there are years when it is very abundant. As for Lake Glubokoye (Moscow Region), the presence of the *Holopedium (Cladocera)* has been recorded; but it has been found only twice during an interval of many years.

If there are no considerable changes in environmental conditions, the list of species varies little in many years; at any rate its changes are rare. Thus, the species composition of zooplankton in Maggiore Lake, Italy (Baldi 1951) has not changed from 1909 to 1950. That of Lake Estwaithe Water, Britain (Smyly 1972) increased from 1923 to 1968 only by the appearance of one species (*Cyclops strenuus*); that of Lake Glubokoye, Moscow Region (Matveyev 1975) from 1954 to 1975 lost one species, namely *Mesocyclops leuckarti*.

The species composition for many years might vary due to direct or indirect human influence. The disappearance of species should be regarded as an indication of considerable changes. This opinion may be supported by unsuccessful attempts at complete extermination of species, which for some reason were deemed undesirable - parasites or farm pests.

A drop in the number of species has been recorded as a result of pollution - for instance, the number of species in Volga River zooplankton were reduced after oil pollution (Konstantinova 1956).

Even in oligomixed biocenoses (consisting of a small number of species), the inventory of species composition requires the work of highly trained specialists. Though there is a small number of species inhabiting salt lakes, we know of 29 species of *Dunaliella*, most of which can be found in strongly mineralized reservoirs (salt lakes) (Masyuk 1973).

Such a work is rendered more complex with the progress of taxonomy. There are poorly studied groups with species which are not easily identifiable. For instance, in may cases it is difficult to determine, or impossible to identify, the dipteran species by their larvae. With the progress in taxonomy some "old" species are being subdivided into several "new" species or, the other way around, they may be combined into one.

A large number of keys for species' identification is necessary.

THE STUDY OF THE HISTORY OF COMMUNITIES BY LAKE SEDIMENTS

To have an idea about the trend of recorded processes, we have to obtain series of data covering many years. The present rate of technogenic dislocation of nature makes it sometimes necessary to have an immediate appraisal. Such secular series of data on the development of communities can be obtained by examining the remains of species in the bottom sediments of lakes which, in this context, are a unique natural object.

Bottom sediments accumulate plants and animal remains in chronological sequence and in definite proportional quantities. The bottom sediment contains the remains of species which belong to the community of the lake proper. They might also include remains of communities from the surrounding landscape in the form of pollen, plant tissue, and seeds. Lake bottom is one of the main natural objects which helps to study historical biocenology and obtain results which are unaccessible through other means. Goulden (1969) remarked quite correctly that at the present rate of pollution of our environment, it might happen that paleolimnology will be the only technique for studying and understanding the development of natural communities.

Lake beds preserve fragments of plants and animals inhabiting the littoral, pelagic, and benthic zones. This type of biological analysis of lake beds is quite adequate since it is representative of the population of all the main zones of a reservoir.

The biological analysis of the bottom of reservoirs might also be applied to historical studies using ground cores, or to analyze the present biocentological type of reservoir using the ground specimens from the bottom surface. The processing of a single sample of the bed gives a fuller inventory of the water flea species than live material for several time periods from a

number of stations, as it has been demonstrated in several reservoirs. Thus, single samples of bed from six lakes in Wisconsin, U.S.A. revealed six species of *Chydoridae* more than all the previous tests over many years; they failed to find only two species (Frey 1960). The examination of seven silt samples from the Ivankovskoye reservoir revealed 31 taxons while only 29 were known as a result of a number of previous collections by special parties. The analysis of single samples taken from ditches of Lake Narskoye, Moscow Region gave a fuller list of species than the samples of live material taken monthly for 2 years; the ditch bed alone revealed eight taxons, whereas only three taxons were in the samples of live material.

The time represented by the cores of lake sediments can reach a million years as in a core of 192.7 m from Lake Biwa (tertiary lake in Japan, Horie 1972, 1974). Usually the cores of lake sediments cover approximately 10,000 years, which includes the time of development of the main civilizations of our world.

The integrated biological analysis of lake sediments incorporates botanical and zoological analysis of lake organisms, pollen analysis, carpological analysis (seeds), the analysis of tissues of macrophytes, and the chemical and physical characteristics. Model works in the field of integrated analysis of lake ground have been carried out by N. V. Korde (1960) and under the direction of G. Hutchinson (1966, 1970).

There has been a considerable development recently in the analysis of animal remains in the bed, primarily of the prevailing fragments of Cladocera (carcinological analysis), insects (mainly of the head capsules of the chironomid larvae), sponges (by spiculae), Protozoa (by their "houses") and some others (Frey 1958, 1959, 1964, 1969a,b, etc.).

It has been proven that zoological analysis of the sediments explains a number of peculiarities of the communities and environment, which are not reflected in plants. Our carcinological analysis of European and Mongolian lakes brought to light several typical cenoses which differ by the dominating species, characteristic successions, and features of initial stages of the formation of the cenosis of Cladocera. More often, but far from always, there are cenoses of *Bosminetum*, *Chydoretum sphaerici*, and *Diaperturetum affinis*. It has been found that cenoses of one and the same types of Cladocera and successions of one and the same type are found in European and Mongolian lakes, which are far from each other.

As a rule a community of water fleas, once it passes the first stage of development, preserves its qualitative type for a long time--with moderate fluctuation. According to Goulden (1969), in the first phase of the appearance of water fleas in a lake, one or two species of *Chydoridae* are extremely abundant, while the others are rare; then comes a phase during which the conventional species become less conventional and the rare ones, less rare; in the third phase, the community is supplemented with rare species.

The increase in the species diversity may commence with the beginning of the formation of association and continue for 200-1,000 years. If, subsequently, there are environmental disturbances owing to the changes of the climate, eruption of volcanoes, or man's activity, the species' diversity might drop and return to the initial stage.

Historical data on the development of biocenosis might facilitate the appraisal, verification, and forecasting of biocenotic regularities studied at modern lake communities, including the historical continuity of the present biocenotic situation.

The carcinological analysis of lake sediment demonstrates anthropogenic disturbances of the environment. Thus, Goulden has demonstrated that the periods of strong increase in the number of water fleas in the East White Water Lake (Great Britain in the post-Atlantic time) coincide with the appearance of neolithic man and with the development of the economic activity of the Normans (Goulden 1964). The number of *Chydoridae* in the La Aguada De Santa Ana Vjeha Pond (Guatemala) increased greatly in the upper 15 cm of sediments which was preceded by a large volume of burnt remains which most likely are the result of brush burning to clear the area that was undertaken in approximately 1760 (Goulden 1966). A strong increase in the relative abundance of *Chydorus sphaericus* in the upper meter of the bottom layer in Lake Nero (Yajoslavl Region) coincides with the period of intensive economic activity in Rostov and environs (the studied core was taken 800 m away from the town site). An in the relative volume of the remains of *C. sphaericus* was noted in the ground - from 8 percent at a depth of 20 cm to 67 percent on the surface. This was found to be a result of fertilizer influence (Mackenthun 1966).

The biological analysis of lake bottom sediments indicates the primary importance of the structure of a community as an indicator, compared to the indicator importance of species. Indeed, the list of species of water fleas in the history of a lake community does not change often, whereas the numerical relationship changes in a characteristic way and demonstrates the real successions and changes in the environment.

The time sequence of deposits is preserved notwithstanding a certain redeposition owing to the activity of bottom animals and hydrological processes (Frey 1969b).

The limitations of the biological method of investigation of bottom deposits in water reservoirs are associated with the fact that not all species are preserved in the ground. Thus daphnias, which are known to predominate, in many cases are rather poorly represented. It is difficult to draw conclusions owing to the fact that there are different types of lakes in different geochemical provinces and different zoogeographical zones. The number of monitored objects has to be increased in order to represent different types of lakes.

It is desirable to develop large-scale integrated biological studies of lake deposits, which definitely facilitate the solution of theoretical and practical ecological problems. Important, in connection with the problem of conserving man's natural environment, is the large-scale application of integrated biological analysis of the upper layers of lake bottom deposits, which illustrate historical changes, including the period of recent industrialization and widespread use of chemicals.

A permanent program of monitoring, using several biological indicators, is in progress on Lake Glubokoye, where one of our oldest lake biological stations (founded in 1891) is operating. A rather large normal range in the level of indicators has been found to describe the state of the zooplankton community and the physiological condition of fishes, in particular the differences for different years (data of V. F. Matveyeva and L. L. Smirnova).

The identification of anthropogenic influences is rendered more complicated by the presence of natural fluctuations, both short-term and long-term, by the existence of different types of lakes, by their location in different geochemical provinces and biogeographical zones, and by the natural production of biologically active substances.

The following scientific and administrative questions have to be considered:

- the minimum list of lakes for monitoring biological fresh-water systems;
- a list of monitored communities, species, and indicators;
- periodicity of observations, techniques, the amount of obtained data, and methods of processing and evaluation;
- intercalibration and standardization of instruments and techniques;
- coordination with other international organizations and unions;
- the training of observers, financing, and legal aspects; and
- ensuring taxonomic studies and establishment of centers for identification of species and taxonomy.

Implementation, today, of methods that analyze, at various levels, our disturbed natural environment will determine tomorrow's degree of success.

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The Ecology of Microorganisms and Biosphere Reserves

by

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Bacteria are, most likely, the last remaining group of living organisms in need of protection by means of establishing biosphere reserves. No matter what extent the technogenic changes of the biosphere may reach, bacteria will find a place in life, even if they have to inhabit the cooling pipes of atomic reactors, as they are doing at the present time.

The biosphere reserves are established to protect the flora and fauna in natural conditions, i.e. to preserve the gene pools; however, from the point of view of some microbiologists, bacteria in natural environments should not even be considered an object of microbiology, but rather should be classed with nature-study. These microbiologists suggest that bacteria are an object of research only when isolated into pure culture in a nutritive medium of a definite chemical composition. This point of view has been formalized by the 1975 Bacteria Nomenclature Code. The logic of this trend reduces the world of bacteria to an aggregate of standard culture in collections, and the first accidentally isolated clone is recognized as the standard. Subject to protection is the gene pool amassed in collections (Zavarzin 1974).

In contrast, there is a biogeochemical trend of thought which has been developing in recent years, and which investigates the rate of biochemical transformations, carried out by microorganisms in nature, without determining the specific agents of the process. The rate of reactions is studied by sensitive techniques of modern chemistry, while biochemical processes are distinguished from abiogenic ones by conventional techniques (traditional for the 19th century) in which sterilized and nonsterilized samples of water or soil are compared.

The formation of ecological microbiology which began in our country on the basis of works by S. N. Vinogradsky and B. L. Isachenko, requires another approach. The motive power of any biogeochemical process in this case is the specific group of microorganisms which act as catalysts of the process. Consequently, priority in this case is given to a system of microorganisms endowed with specific functions like that of anaerobic decomposition of cellulose, methane production, reduction of nitrates which interact with a system of external conditions--the rate of arrival of oxygen, of the allochtonic organic matter, sulphates, and calcium. The final result is an overall pattern which describes the interaction within sulphureta or methantank.

Precisely, this trend yields the most data about new microorganisms.

Ecologists of bacteria are, more than anyone, aware that there is no sense in protecting a species in nature. The necessary thing is to protect its life conditions. Such biotopes can be very small, like thermal springs where peculiar cenoses of procariotic organisms exist. Just a few of these Procaryota have become available for laboratory examination, and even that happened only recently. Peculiar cenoses develop on oxidizing sulphide deposits, ferrous springs, etc. In general, it may be said that the microbiologist is interested in protecting such places in nature where we currently see intensive geochemical processes.

Microbial cenosis, however, requires an ecological approach not only in these peculiar places. It is precisely the microflora of regions where the processes are at equilibrium and where the arriving substance is completely processed at the geochemical barrier, the durable existence of which is possible while it is maintained by microorganisms. Precisely, this microflora is the most difficult to cultivate in laboratory conditions (Zavarzin 1976).

This shows that our knowledge of the group and species composition of microflora, in its main spheres of habitation--including waters and soils--is insufficient. Nevertheless, the available data can be regarded as adequate for formulating and even resolving some questions on the role of the microbiological factor in the biosphere and in the protection of the environment.

Let us now examine the micropopulation of the soil. The diversified microworld of the soil can be divided into groups interrelated by the influence of a range of factors, the first being metabiotic factors (Mishustin 1972). This covers the following groups, each incorporating many genera of microorganisms belonging to various systematic groups:

1. Saprophytes (zymogenous microflora)--decomposing plant and animal remains.
2. Mineralizers of humus (autochtonic microflora).
3. Oligotrophs--mineralizers of residual substances of various origin.
4. Autotrophs--organisms which transform mineral compounds and whose metabolism is based on oxidation of different inorganic substances.

The absolute number of microorganisms in different soils is not the same. From north to south, the soil mass becomes increasingly enriched by microflora. Accordingly, there is an increase in energy of microbiological processes. In the main, this is a reflection of the temperature factor (Mishustin 1947).

A similar pattern is observed in the grouping of the autochtonic microflora. The ratio of the saprophytic and oligotrophic microflora narrows with transition from north to south. An explanation is that the products of organic decomposition

(plants, animals) in a colder climate decompose slower which makes possible the accumulation of a larger mass of oligotrophs in the soil.

To understand the species composition of the mentioned groupings requires the pooling of efforts of different specialists. At the present time the most extensively studied are the saprophytic organisms. A series of species of bacteria, actinomycetes, and fungi have been identified as indicative for certain soils. It is common knowledge that most microorganisms have a tremendous range of natural habitat. It is also determined, however, that optimum conditions for reproduction of certain species of microorganisms develop only in certain soil-climatic zones. Therefore, the spectrum of dominant species for definite soils is highly specific. The confinement to definite types of soil was also observed in some representative of the autochtonous microflora.

The oligotrophic microorganisms are much more numerous than the saprophytic microorganisms. Their detailed study is only in its initial stage. Preliminary data give grounds to conclude that here we commonly find highly interesting (morphologically and physiologically) microorganisms.

The natural cenosis of microorganisms changes radically when soils are cultivated (Mishustin and Pertsovskaya 1954). Even the mechanical effect of ploughing alters the established environment. The improvement of the air and water regimens in the soil intensifies a number of processes and alters the compositon of soil micropopulations. The influence of chemicals (fertilizer and pesticides) aggravates this process. The composition of the micropopulation as a rule, is substantially altered by cultivation and becomes similar to the soil microflora of a more southern zone.

The explanation of the influence of the soil cover upon the environment--the sources of water supply and air--should be carried out by comparing the processes in the natural environment and in the conditions produced by agriculture. This affords the possibility of understanding not only the scientific aspects, but also the essential practical questions (transport of minerals and organic matter from soil to water courses, formation of toxic compounds, isolation of gaseous products from soil, etc.). It is also known that soil cultivation is a source of a number of compounds which worsen the quality of water, like nitrates, pesticides, etc. Therefore, the knowledge of the transformation of these substances in different soils can offer valuable practical information.

The influence of soil on the atmosphere is less clear. Therefore, we have decided to discuss this in more detail.

The present atmosphere took shape on the Earth when the surface layers were unaltered by human activity. At a time of increasing pressure upon the resources of the Earth, it is doubtful that the atmosphere will be able to reestablish its composition. The

relevant argument, usually, is the annual increase in CO_2 by 0.2 percent throughout 1958-1969. Study of the chemical composition of the atmosphere's lower levels depends upon disruption of the subtle balance between the formation of trace quantities of substance from various sources and removal of these substances by various mechanisms (Rasool 1973). The time of presence for easily soluble components of the atmosphere is several days, while for substances which are difficult for solution, the time is measured in years and even dozens of years. The available estimates of the sources of microcomponent entry into the atmosphere indicate that the value of technogenous production is usually less than 1% of natural biological sources; for some components, like nitrogen oxide, however, it reached several percent. Thus, on a global scale, the violation of biological processes in the biosphere can affect the composition of the atmosphere greater than the local production of gases by industry.

Lovelock and Margulis (1974) some time ago, comparing the composition of the Earth's atmosphere with the atmospheres of the lifeless Mars and Venus, concluded that the Earth's atmosphere does not agree with the expected surplus of nitrogen. It is known that nitrogen in equilibrium (thermodynamically conditioned by the composition of the Earth's atmosphere) should have passed into nitrates of the ocean. Lovelock and Margulis suppose that photodissociation of water vapors could have ensured this reaction by an adequate amount of oxygen.

Whatever the original composition of the Earth's atmosphere, it may be definitely stated that an atmosphere similar to the contemporary one had been formed by the time eucariotic organisms appeared in the Earth. Possibly the oxygen content in that atmosphere was lower than when multicellular animals and plants first appeared. This follows primarily from the fact that all eucariotic organisms are aerobic. Thus, an atmosphere qualitatively similar to the contemporary one was formed in slightly more than 2 billion years of the existence on Earth of a procariotic ecosystem. Hence, procaryotic organisms are capable of influencing the components of the atmosphere and, possibly, maintaining its composition even at the present time. This idea can be verified by comparing the possibilities of procarioties and eucariotes.

Among the soluble gases, the most important is carbon dioxide whose cycle has been studied in considerable detail. The biological peculiarities of carbon dioxide metabolism in growing plants, besides the technique of assimilating it are also characteristic of the procariotic cyanobacteria--the ordinary inhabitants of internal reservoirs. The products of their gas metabolism enter the atmosphere, prior to becoming balanced with the water mass of the ocean. The concentration of carbon dioxide sharply increases in the soil air, where it reaches 10%. Two thirds of this carbon dioxide is formed in the respiration of microorganisms. A question arises, as to what extent the acceleration of the decomposition of organic substances in cultivated soil, with its better gas metabolism, facilitates the entry of carbon dioxide into the atmosphere?

Oxygen produced in photosynthesis is balanced in the geochemical cycle with carbon dioxide. It polluted the original atmosphere of the Earth, appearing in great volumes as the result of the photosynthesis of cyanobacteria. Its low concentrations, in the order of 0.1% of the present, could have appeared as the result of abiogenic reactions. This concentration of oxygen in presently known aerobic organisms is applicable for microaerophilic bacteria like spirillas and hydrogen bacteria. The present-day concentration of oxygen is close to the top limit for many organisms, bacteria included. Great concentrations of oxygen are controlled by its accelerated consumption for decomposition of organic substances as oxygen blast in aerotanks. Recent green plants, which have substituted cyanobacteria in the ecosystem, perform the same role as their precursers; but in the quantitative aspect, their contact with the atmosphere is more effective. The relationship of higher plants with the remaining gases is accidental and at times pathological as in plant-indicators of pollution.

Nitrogen in anabolism is utilized by a variety of different procariots possessing the nitrogenase enzyme. Eucariotic organisms do not have this ability. The enzyme, with its genetic apparatus, might be passed from one bacteria to another; the higher plants, notwithstanding all evolutionary advantages, are confined to bacteria-symbionts. The ability to fix nitrogen is possesed by many anaerobic organisms, like clostridias and sulphate-bacteria and by some aerobics, including the corinebacteria and the blue-green algae. The global volume of azotofixation is so large that, according to some estimates, it shifts the balance to nitrogen binding.

The main product of binding is ammonium, which appears in the atmosphere over places of decomposition of organic remains. The curve of its distribution in the atmosphere indicates the existence of source and discharge near to the earth. The pathways of its conversion, unassociated with anabolism, are fully preconditioned by procariotic microorganisms--nitroficators which develop oxide forms of nitrogen: nitrites, nitrates, and nitrous oxide. Ammonia production is 1,000 megatons per year.

Nitric oxides appear in the disbalance of the microbial ecosystem whenever there is an increased formation of nitrites. The annual output of nitric oxides by soil bacteria is estimated at 1,000 megatons compared with the 50 megatons of technogenic origin. Nitric oxides are the main propellants of the photochemical cycle in the atmosphere. Though their formation by microorganisms has been known since the 1880's, the microbial aspects of their transformation in nature has not received due attention. The activity of specific groups of bacteria, nitrificators, and deniftrificators is associated with nitric oxides.

Nitrous oxide holds a special place, owing to its poor solubility and reactionability. In nitrification, it can comprise up to 20% of oxidized ammonia; in denitrification its

amount varies, comprising a noticeable part of the gas. Besides biological reactions carried out by microorganisms, we do not know any ways of the formation of this gas with an annual output of 600 megatons. The only means of removal, not counting photo-dissociation in the stratosphere, is consumption by denitrificators in anaerobic conditions.

The entry of nitrogen into the atmosphere is associated with the functioning of a specific group of denitrificators--optional anaerobic organisms which intensively reduce oxidized nitrogen compounds to molecular nitrogen even at low oxygen concentration. This function is only characteristic of procariotic organisms, and apparently nothing but this function equalizes the thermodynamically possible accumulation of nitrates in natural waters.

We have not touched upon the nitrose-compounds formed by microorganisms even though they are of physiological importance without playing a qualitative role in the atmosphere.

Hence, completing the review of the influence exerted by microorganisms on the nitrose components of the atmosphere, it may be stated that bacteria could have both formed the present-day nitrogen-containing atmosphere of the Earth and maintained its composition. They and they alone, of all living matter, possess the indispensable enzymatic systems to exercise that function.

The next group of microcomponents of the atmosphere is comprised of combustible gases. It is expedient to start reviewing them by taking up hydrogen which, according to many geochemists, was an important component of the Earth's original atmosphere. It is practically nonexistent in modern atmosphere. Its sources are the eruptions of volcanoes and the decomposition of organic matter in anaerobic conditions, where it is an indispensable product of oleo-acid and formic fermentation. In the anaerobic zone, however, this gas is consumed by specific groups of microorganisms: sulphate-reducing, methane-forming, homo-acetic, and photo-synthesizing ones. The product of sulphate reduction is hydrogen sulphide with an annual input to the atmosphere of nearly 100 megatons; the product of methane-formation is methane with an annual input to the atmosphere on the order of 500 megatons. Both values are greatly diminished because most of the indicated gases are oxidized by strictly specific microflora of sulphur bacteria and methylotrophes, and do not enter the atmosphere.

Moreover, oxidation of hydrogen is exercised by various hydrogen bacteria forming water as the end product of their catabolism. These bacteria are capable of extracting hydrogen from the atmosphere even at low concentrations. On the other hand, hydrogen bacteria are capable of utilizing negligible concentrations of oxygen. The ecosystem within which hydrogen bacteria play the role of primary producer corresponds well with the hypothetical original atmosphere of the Earth. In the future, these organisms, which produce up to 50 g/l of dry biomass, might be the most advantageous source of protein for mankind, if a cheap

technique of hydrogen extraction is found. Unlike photosynthetic systems, there is no necessity, in this case, to make use of the illuminated surface of the Earth for growing farm plants which is the process that creates the greatest disruption of equilibrium in the biosphere.

The most characteristic technogenic pollutant among the combustible gases was considered carbon monoxide; however, recent isotope determination has shown that there is another natural source with a capacity surpassing the technical output 20-fold. It is supposed to be the decomposition of chlorophyll. The means of removing CO from the atmosphere remained unclear. The laboratory of one of the authors described recently a group of carboxide bacteria which perform CO oxidation according to the equation:

$$25\ CO + 12\ O_2 + H_2O = 24\ CO_2 + (CH_2O).$$

For some carboxide bacteria, the atmosphere with 80% CO is optimal. Thus, the means of removing this gas is also controlled by bacteria (Mishustin and Pertsovskaya 1954).

Summing up, it may be stated that the microcomponents of the atmosphere are influenced by specific microorganisms which mostly belong to litotrophic ones whose detailed description has been given recently by Zavarzin (1972). Bacteria alone, of all living organisms, possess the necessary functions. The components of the two most active photochemcial cycles in the atmosphere--methane and nitrous oxide are bacteria-produced. The supposed original composition of the atmosphere could have been altered by bacteria of precambrian ecosystems towards the contemporary qualitative composition.

The atmosphere is the most common component of the biosphere for all living organisms; changes in its composition are transferred throughout the Earth very quickly.

The atmosphere in which man orginiated as a biological species corresponds to protected parts of the biosphere untouched by man's activity; biosphere reserves are the example.

The atmosphere is in a state of kinetic equilibrium with soil air which is formed mostly by microorganism activity.

The comparison of components of the atmosphere with the operation of specific physiological groups of microorganisms indicates that the concentration of these components is under the influence of definite procaryotes which, alone from all living organisms, possess the appropriate enzymatic activity.

Taking into consideration the length of time that an exclusively procariotic ecosystem has existed on Earth, one may suppose, with considerable conviction, that the Earth's atmosphere was formed greatly due to the activity of bacteria.

It follows that microbiological studies in biosphere reserves are indispensable and should occupy a respectable place in the general program of observation.

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Population Genetic Aspects of Biosphere Reserves

by

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The idea of biosphere reserves as life reserves under natural environmental conditions, which change abruptly, is closely related to the concepts and approaches of a number of biological subjects including population genetics. Genetic approach is of great importance since though the biosphere as a whole undergoes anthropogenic effect today, the results will be realized in changes in the populations--elementary self-reproducing biological units. These populations make up the structure of species included in the ecosystems; thus, the problem of preservation of the available biological communities, and those which are to be brought into being, finally comes down to finding the means to form and stabilize the genetic structure of the population. For this purpose one should have a precise idea of factors of evolution and those internal autoregulation mechanisms which allow them to be steadily reproduced in future generations maintaining balance with the natural environment.

FACTORS AND CONDITIONS OF GENETIC POPULATION STABILITY

Principals of Approach

Population genetics investigate the regularities of conservation and transformation of genetic structure of populations in time and space. The theoretical basis of such a consideration is the well-known Hardy's Law, which describes the fate of genetic information in case of panmixia with an unlimited number outside the habitat. In such a nonstructural community, the genotype proportions and, consequently, gene frequencies approach a steady state in the next generation following the one with panmixia, and remain unchanged in an indefinitely long population succession (fig. 1).

But, such ideal populations practically never occur in nature, since their steady state and stability are disturbed by natural factors. For example, as a result of natural selection, some genotypes will leave more descendants than others, and this will cause a change in the genetic structure of the population. Mutation and gene migration are possible, and the population will also change its genetic characteristic. In addition, accidental genetic drift can take place when population numbers suddenly decrease and an erroneous gene transfer to the next generation is observed.

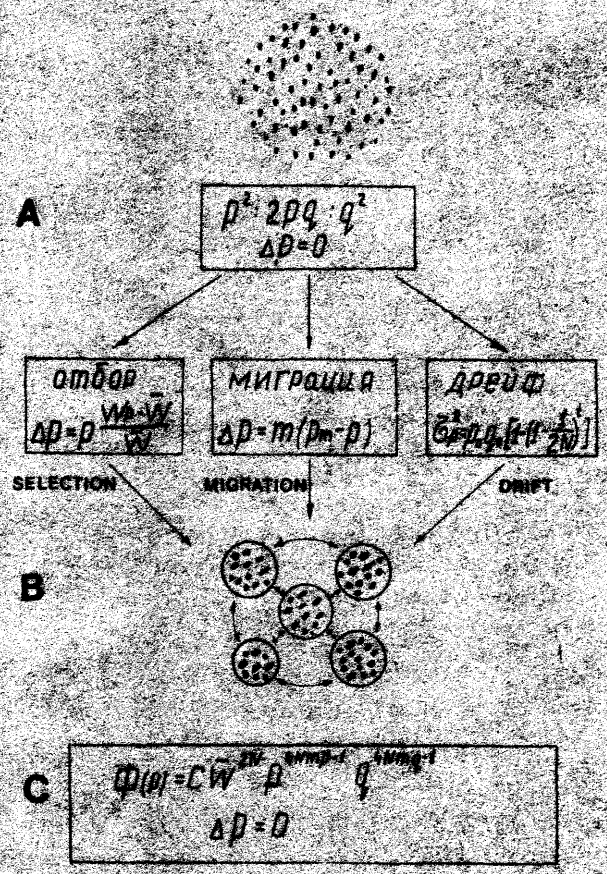

Figure 1.—Basic Mathematical Model for Population Genetics. A. Panmictic population of unlimited size, remaining stable ($p = 0$) in the absence of selection (w), migration (m) and random gene drift (N)—the so-called Hardy-Weinberg law, represented by the formula 1, where p and q = frequency of genes combining at random in homozygote (p^2 and q^2) and heterozygote (pq) gene types; II, III, IV = elementary formulae for selection, migration and drift, as basic factors in gene frequency changes (Δp); B. Subdivided population, formed as a result of simultaneous effect on gene structure of selection, migration, and random drift; C. Mathematical function for frequency distribution of genes in such a population.

All these factors can be assumed to affect the population simultaneously, so its internal structure could become complicated. The panmictic population will be divided into an aggregate of subpopulations united by a certain degree of interaction. The gene frequencies distribution in such a subdivided population will again become stable and stationary, as a result of equilibrium of centrifugal and centripetal trends. These are the so-called microevolution processes described, in broad terms, in the theory of population genetics.

The principal mathematical models of population genetics were developed in the thirties and forties (S. Wright 1931, Dubinin 1931, Dubinin and Romashov 1932, see also Dubinin 1966, Fisher 1930, Haldane 1932), but their application in practice presupposes observance of at least two main conditions. First, genes should be analyzed as elementary units of heredity, and second, their distribution should be investigated in populations which have been sufficiently characterized as integral biological units.

Though outwardly the formulated requirements seem rather simple, it is not so easy to satisfy them. Indeed, gene frequency is a principal population genetic parameter, but it can be characteristic of a population only when the gene has a distinctly pronounced phenotypic effect. For example, if individual

peculiarities of animal coloration are controlled by allele genes, this leads to several hereditary morphs, differing in said above characteristics. Such a variability is called genetic polymorphism and can be easily investigated. But many species have no polymorphism, are outwardly uniform, their genes are hidden from the observer, and consequently, a direct population-genetic analysis is impossible. That is why until recently the genetics of natural populations was restricted to a small number of outwardly polymorphic species. Only in the last decade, due to success in immunologic and biochemical genetics, have considerable changes taken place. A system of allele genes, coding the synthesis of blood group and various proteins of enzyme and nonenzyme nature, have been discovered in a number of species. This "hidden" hereditary variability is discovered either by immunological reactions or electrophoretic methods. For example, the hereditary electrophoretic variants of enzymes of lactat-dehydrohenese and phosphoglucomutase have been described for Pacific salmon *Oncorhynchus nerka* Walb by American and Soviet investigators (Hodgins and Utter 1969, Utter and Hodgins 1970, Altuckhov 1974) by means of field techniques of protein electrophoresis in starch and acrylamid gels. The discovery of broad biochemical hereditary variability of natural populations gave a new, previously unknown, possibility for their comparative investigation; and this today is becoming a central direction in population genetic studies (fig. 2). The following important condition is connected with the choice of the object of investigation. Any biological branch has its own research subject: molecule, cell or individual. Among cytologists, anatomists, or physiologists there is no disagreement on reality and integrity of their investigated levels. But when we turn to ecology or population genetics we do not find such unity--one can count more than 10 terms used to designate intraspecific categories in animals and plants: "population", "Mendelian population", "deme", "ecotype", "morph", "microtopographic race", etc.

A universal terminology, which does not allow ambiguous interpretation, is the index of maturity of any branch of science. It is evident that it does not pertain to population biology since it is still undergoing the analytical stage of development, reflecting the separate interests of morphology, taxonomy, ecology, and other biological branches that are much interested in population levels of life organization. At the same time, it becomes more evident that variability of terminology points to some fundamental peculiarities of the population level which are unfortunately not always taken into account. First and foremost is the variability of the level caused by its internal characteristic principle of hierarchical construction. Only when this circumstance is taken into account will a comparative population-genetic investigation be possible. Further, we shall examine basic results obtained by incorporating such an approach into the study of isolated natural populations.

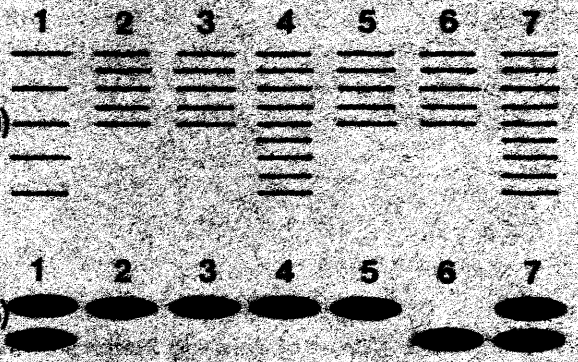

Figure 2.--Hereditary electrophoretic variations of the enzymes malatedehydrogenase (a) and phosphoglucomutase (b) in the Pacific salmon *Oncorhynchus nerka*. a-1-7: heterozygotes. 2, 3, 5, 6-homozygotes of one type, 1-homozygote of another type (electrophoresis in acrylamide gel); b-1 and 7-heterozygotes, 2, 3-6-homozygotes (electrophoresis in starch gelatin).

NATURAL POPULATIONS AS HISTORICALLY ESTABLISHED GENETICALLY STABLE POPULATION SYSTEMS

The most complete data available are for economically valuable species of fish, under investigation since 1962 at the biological faculty of Moscow University, in the Institute of General Genetics, U.S.S.R. Academy of Sciences, and in the Institute of Marine Biology-Far East Scientific Center, U.S.S.R. Academy of Sciences. Populations (so-called local stocks) existing within natural isolating borders, formed at least thousands of years ago and described in detail biologically, were chosen as investigation objects.

Under field conditions, we studied various gene markers (blood group and protein) of tens of thousands of fish caught in self-maintaining native populations--not yet destroyed by fishing or other external effects. These populations included: sea perch *Sebastes mentella* Travin in the northwest Atlantic, European anchovy *Engraulis encrasicholus* in the Black Sea and the sea of Azov, red salmon (nerka) in one of the lakes of Kamchatka and Sakhalin salmon (*Oncorhynchus keta* Walb.) still surviving in populations artificially maintained for several generations at fish-rearing plants. Let us consider the most important results of these works, taking as an example the sea perch stock, located near Newfoundland, and an isolated population of nerka.

Newfoundland is shown in figure 3. On the right hand is a continental slope where perch concentrates. This slope is a continuous line hidden by a thick layer of sea water. Individual points indicate the location of trawling stations. The expedition vessel trawls continuously from top to bottom; and fish from each catch are selected for classification according to both hereditary peculiarities and biological characteristics, such as body length, sex, age, and stage of maturity. The hereditary heterogeneity of the stock can be illustrated on a so-called genogeographical map (fig. 4). We see fields of various gene frequencies or concentrations. This points indirectly to the fact that the school[1] investigated can be differentiated into smaller ones which differ

[1] School can probably better be translated as "stock" here and elsewhere in this article.

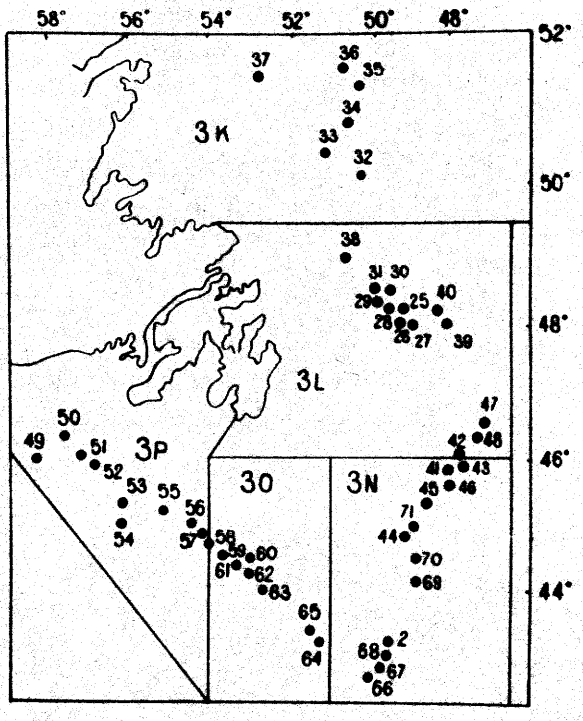

Figure 3.—Chart of Trawling Stations in the Newfoundland Sea Perch (*Sebastes mentella*) Area.

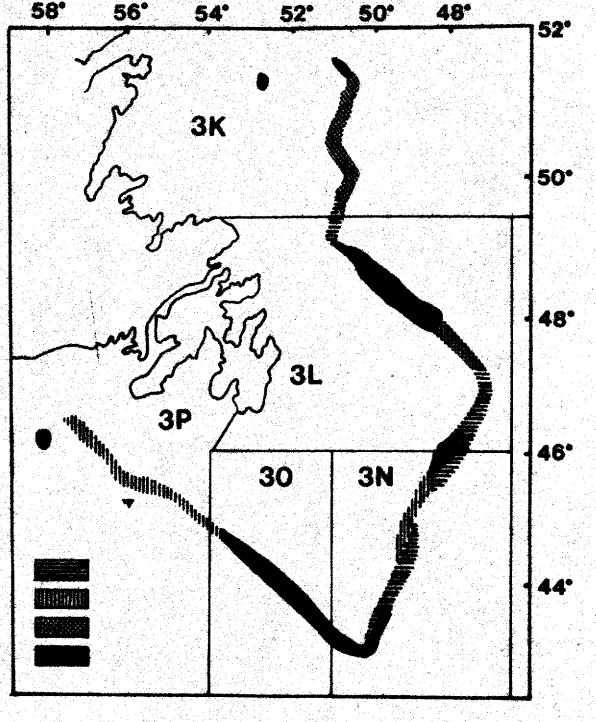

Figure 4.—Gene-geographical map, demonstrating hereditary heterogeneity of the school. The streak shows the geographical difference in the frequency of encounters with gene-carrier fish, coding a specific blood type: 1-0.35-0.50; 2-0.50-0.65; 3-0.65-0.80; 4-0.85-0.95.

from a genetic point of view. Indeed, if we analyze the variability of the above-mentioned biological characteristics, we can detect within the school an aggregate of biologically homogeneous, but at the same time, differing groups. These are the so-called elementary populations, each characterized by a specific gene pool (Altukhov et al. 1969 a,b).

A population structure of a local school of one species of Pacific salmon - nerka which reproduces itself in Azabach Lake, Kamchatka, is shown in figure 5. The points denote individual spawning areas inhabited by various elementary populations. They can be directly observed, thus there is no need for the labor-consuming work of contouring them.

What is the meaning of such differentiation of a species or a local school? Are they independent populations or parts of a whole such as a school? Ecological observations show that such subpopulations remain as parts of the whole, since none of them covers the whole genetic variation typical to the school; and besides, they interact constantly via gene exchange. Thus, an individual local school is turned into a system of populations connected by interaction. The results of a detailed 4-year investigation of the nerka school at Kamchatka showed a satisfactory agreement with a natural situation of an "island" model for population structure, as suggested by S. Wright (1951). The range of real genetic variability of populations (a histogram) is shown in figure 6 compared with a theoretical distribution of gene frequency (curves). One of the theoretical curves (1) does not evidently correspond to an empirical distribution. In this case

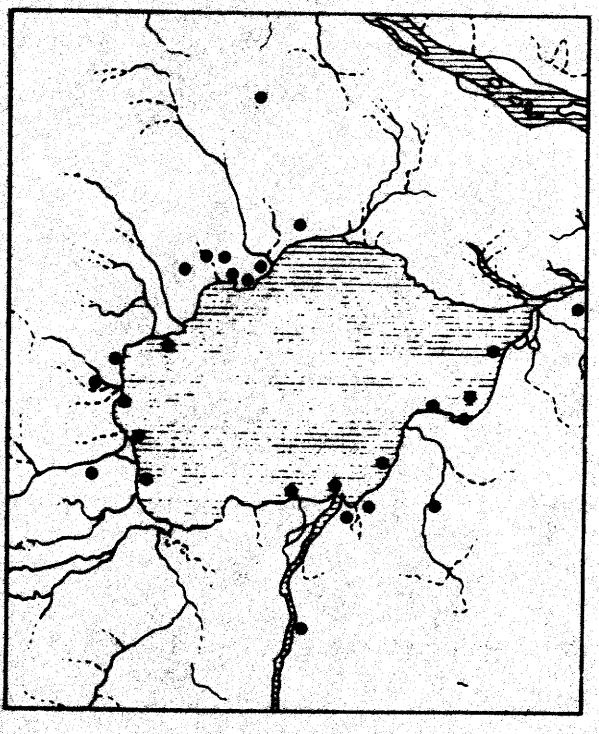

Figure 5.—Locations of separate elementary populations, making up the reproductive structure of the red salmon *(nerka)* of Lake Azabachievo in Kamchatka. The black dots —spawning grounds, where fish were caught immediately after spawning.

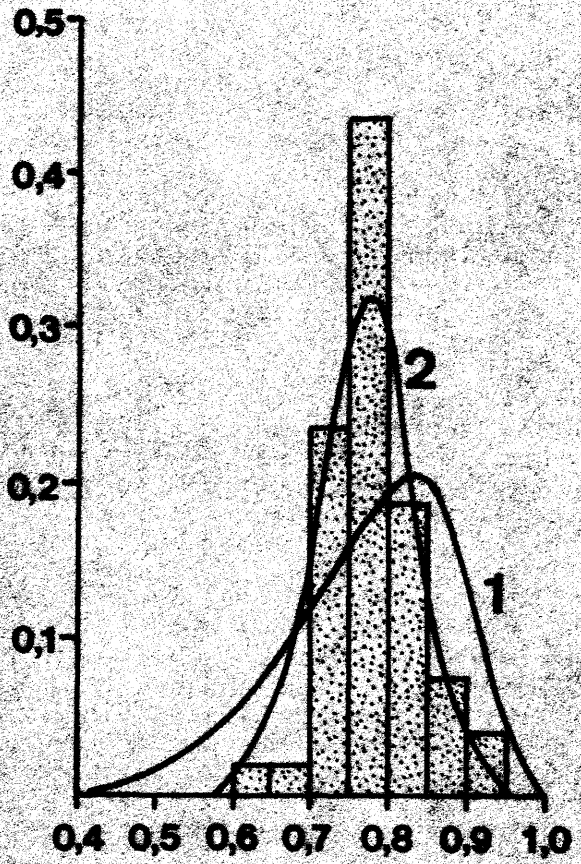

Figure 6.—Actual (histogram) and theoretical (1,2) gene frequency distribution of phosphoglucomutase in the Lake Azabachye red salmon population. 1-with ignoring the factor of selection, 2-with selection pressure. Along the abscissa-gene frequency, along the ordinate—percent of population with the given gene frequency.

the calculations were performed on the assumption that the steady state of the system was set by the balance of migration pressure and an accidental gene drift, caused by a low number of individual subpopulations. The other curve (2) agrees well with empirical data. Here a selection factor is introduced into a model which, as was ascertained, contributes to heterozygous genotypes (Altukhov et al. 1975 a,b).

Thus, in spite of the genetic differentiation of elementary populations, a school, as a whole, remains in equilibrium; and what is of particular importance, this stability reflects its adaptation to a certain natural environment. In the case of environmental shifts which remain within the historically established adaptation optimum, it is this subpopulation variety that serves as a guarantee of the stability of the population system in time and space. If a comparative approach is applied, one will succeed in detecting long-term stability of population systems in time. Despite the variety of their parts, such steady-state genetic processes can be illustrated with several examples.

Figure 7a shows the genetic stability of three successive generations of an Azov anchovy school, differentiated as in other species into elementary populations. The vertical axis denotes gene frequency and the horizontal axis shows samples from in-

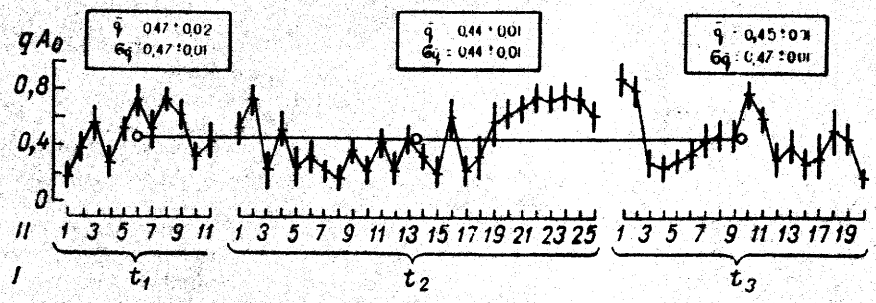

Figure 7a.—The genetic stability of the population of Azov anchovies as a whole, as against the background of variability of separate structural components in subsequent generations t_1, t_2, t_3.

dividual elementary populations which make up a reproductive structure of the school in three successive generations without overlap. The dashes parallel to the horizontal axis denote the values of the gene frequencies in the samples and the vertical columns show 95% confidence intervals. It is clear that in spite of variability in parts, such a subdivided population maintains itself as a whole in the investigated interval.

The second example (fig. 7b) refers to *Drosophila pseudoobscura* whose population genetics were investigated, in particular, by many American authors. Th. Dobzansky investigated the frequency evolution of one of the chromosome inversions in California populations. Using the same approach to the subject, one can also show the stability of this population which is usually considered as one undergoing evolutionary transformation. Here the stability of the system has been observed for 70 generations.

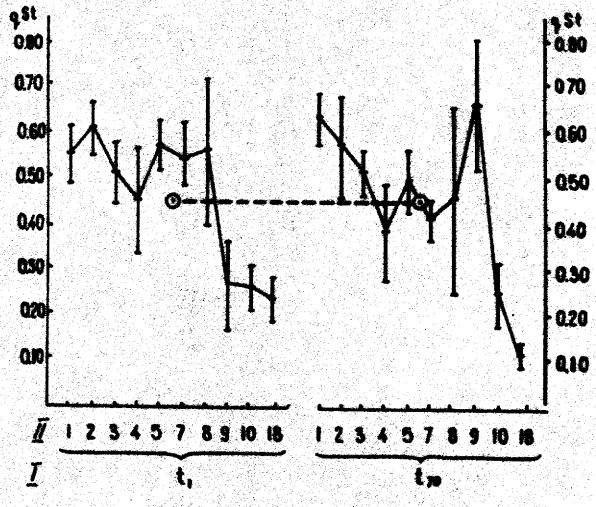

Figure 7b.—Genetic stability of a Drozophyl population in a 70-generation interval, as against the background of variability of separate structural components. According to F. Dobzhanskii's data.

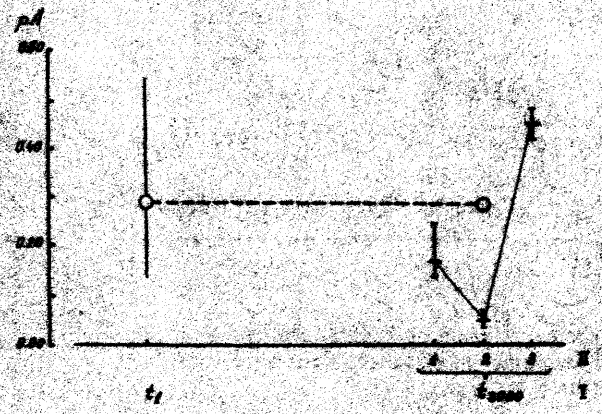

Figure 7c.—Genetic stability of a littorine mollusk population in an interval of 2000 consecutive generations. t_1 = ancient, "pre-population" (total: pA = 0.267 ± 0.026; N = 479), t_{2000} = present populations represented by 3 subpopulations (pA = 0.273 ± 0.01; N = 3818). Vertical axis = gene frequency as basic population-genetics parameter. Horizontal dashes = gene frequency of samples, vertical = 95% confidence intervals, demonstrating the statistical reliability of the data. Circles = average values of gene frequency for the system as a whole.

And as a last example, we'll consider the gastropod *Littorina squalida*, inhabiting a rather isolated lagoon at Busse, Sakhalin. This object is of interest, since its gene effect is "recorded" on the shell surface as a design, which is preserved on the fossil as well. The age of fossil shells was estimated at 5-6 thousand years. This means that the modern population is separated from the ancient one by approximately two thousand successive generations (fig. 7c). Nevertheless, even under changed conditions of the isolated lagoon the population, subdivided into subpopulations, preserved all of its hereditary information.

Thus, the conclusion can be made, that in a definite way planned genetic investigation of natural populations reveals their organization system. This conclusion has both theoretical and principal practical value--if we are indeed discussing a system, then one should consider it as a whole taking into account its internal genetic variation.

CONCLUSIONS

The more complicated the organization of the population system, the more stable it is to various external effects; and consequently one and the same regularity should be observed at any level of biological integration, including species, communities and the biosphere. It is possible to point out that the organizational principles and stability conditions of the biological systems remain universal, that is, *stochastic regulation through the interaction of relatively independent structure components, exchangning information on its own state and that of the natural environment.* Both long term survival of the community in a stable environment and its ability to respond expediently to various external effects, without exceeding its adaptation optimum, are possible only on the basis of maintenance of historically established directions and the intensity of information flow. While planning the means to optimize the interaction between man and the natural environment, the determination of these limits presents an urgent problem; and the investigation of

biological and genetic processes on the basis of biological preserves should promote its practical solution.

The most important problem of optimum relation between anthropogenic and natural landscapes, both in individual regions and with the biosphere as a whole, ought to be considered from the same standpoint. Obviously, a situation in which the interrelation between natural and anthropogenic landscapes is mutually-complementary seems to be correct. By pure intuition, this approach is already used nowdays, for example, in town-building, but the extent of its quantitative substantiation remains unknown.

Finally, one should emphasize another important aspect of the investigation of genetic processes in biosphere reserves. As was already said, any natural population undergoes the pressure of spontaneous mutation, which changes its genetic structure. Since the frequency of such events is not high (approximately 10^{-5} to 10^{-7} per gene per generation), we did not consider the effect of this factor in this paper. At the same time, the problem of a possible mutation rate increase in the populations, due to environmental pollution, is of extreme importance today and is attracting the attention of many scientists. From that point of view, the organization of preserved areas and long-term observation of genetic processes in native populations can be of great importance for the evaluation of rates and directions of mutation processes in related populations dwelling outside the preserve zones and undergoing corresponding external effects.

In conclusion, the following system of measures, directed towards the optimum interrelation between man and nature on the basis of biosphere reserves as sources of historically established genetic variation, can be outlined:

1. In population genetics terms, the organization of biosphere reserves as representing principal natural zones of the Planet this means conservation of surviving native population systems. The total area and structure of preserve zones should be determined so as to provide for their stable existence despite external effects from contiguous anthropogenic landscapes.
2. Biosphere reserves can be used as gene plasma banks to restore the population systems whose internal structure is disturbed as a result of their irrational economic usage or other extreme external effects. They should also be used to generate new systems in those natural habitats where historical, geographical and economic possibilities promote the required conditions for such measures.
3. Monitoring of genetic processes in biosphere reserves is undertaken to forecast environmental state and to substantiate the "departure point" for evaluation of the rates and direction of the evolution of populations and species under the influence of anthropogenic effect, including possible environmental pollution by mutagenes.

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The Study of Long-Term Changes in Terrestrial Ecosystems at Biosphere Reserves

by

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Man's influence on the environment, which has presently reached tremendous scope, commenced in remote times. Most likely, as far back as in the neolith, it led to the emergence of the first derivative ecosystems. A question arises in this respect as to what extent the different types of natural biogeocenoses retain their primary structure? The answer to this question is necessary for a proper appraisal of the state of the biosphere and, in particular, for a comprehensive characterization of the standards of the natural environment retained in biosphere reserves. It can be obtained after a thorough examination of the evolution of ecosystems in historical and prehistorical times.

The continuous development of primary and derivative biogeocenoses leads to secular successions, many of which take place notwithstanding human activity. When, however, natural resources are used for economic needs, biogeocenoses are ordinarily regarded as relatively stable ecosystems and their evolutional changes are not taken into consideration. This approach cannot be justified. Our knowledge of Holocene time gives grounds to believe that long-term successions might evoke considerable changes in the ecosystems in time periods commensurable with the life of only several generations of people. At this rate of succession, the study of the evolution of modern biogeocenoses, besides its theoretical interest, acquires serious practical significance. It is necessary for the clarification of general developmental trends and for advance forecasting of the stated Earth's ecosystems.

The study of the history of biogeocenoses incorporates research into the history of individual components of ecosystems, the development of the ecosystem structure and the relationships of ecosystems. Data illustrating the mentioned processes are ordinarily obtained by studying natural deposits of soil, plants or animals. Frequently, the taxonomic composition and the abundance of various species in these deposits are predetermined not so much by the character of ancient associations, as by the conditions of death, accumulation, and conservation of dead organisms. Therefore, their value for paleoecological studies is not the same. Of greatest interest for the study of relationships and the structure of biogeocenoses are peat bogs and lake bottom sediments, cave accumulations of caprolithes and bird food remains,

archeological relics, and present-day settlements of mammals which make deep and intricate burrows.

The paleobiological study of peat bogs and lake sediments began a long time ago. Its results are the foundation of contemporary notions of the Holocene history. They are well known, and we will not dwell on the taxonomic peculiarities of this most important source of information.

Many cave overhangs and niches that have formed in hard rock are places of permanent habitation of animals. The accumulations of excreta and pellets left in those places by birds are, in many cases, quite considerable. The range of fragments of plants, bones, and chitin contained in these excreta, unlike the conventional tanatocenoses, reflect the functional structure of a part of an ancient ecosystem, parts of which were the hosts of that shelter. Layer-by-layer taxonomic analysis of that material and its dating by radiocarbon techniques reveals the gradual alteration of biogeocenoses in the Holocene and at times in the Upper Pleistocene. In those cases where geological peculiarities of the locality prevent ground water and atmospheric precipitation from entering the cave, the composition of the excreta of herbivores makes it possible to detect the long-term changes in the mobility of different chemical elements in the soil-plant system. This opens up the possiility of reconstructing the climatic conditions of the past (Martin et al. 1961).

The chemical analysis of accumulations of excreta in caves can be used for studying the industrial pollution of ecosystems by the heavy metal compounds (Petit and Altenbach 1973).

The burrows of mammals with nest chambers below the alluvial soil horizon are exceptionally interesting paleoecological relics. Such burrows are built by *Alopex, Vulpes, Meles, Hystrix, Marmota,* and some other animals. They are repeatedly reconstructed, rendered more complex, and used by many generations of animals. This is accompanied by covering the adjacent sections of ground, remains of vegetation, bones, excreta and food of the hosts, and fragments of skeletons of their tenants and accidental visitors. Present-day burrows are peculiar burials of parts of an ancient biogeocenosis. Their study by present-day techniques of paleobotany, paleozoology, paleopedology, and geochronology reveals interrelated changes in the climate, soil-forming process, the plant cover, and the animal population of the surrounding territory (Dinesman 1968). The majority of contemporary marmot, badger, and Arctic fox burrows originated in the Middle Holocene; approximately 10% exist since the early Holocene. Even older burrows have been found. One of the oldest badger burrows was recently found in the German Democratic Republic on terminal moraines in Meklenburg (Diebel and Heinrich 1970, Peters et al. 1972). The bones buried in it revealed fragments of the skull of *Citellus* (*Colobotis*) ex gr. *major*, which lived in Western Europe in the Pleistocene.

Archeological monuments are similar to old burrows of mammals in the variety of buried biological material. They cover practically all stages of the development of human society and illustrate the natural peculiarities and character of the economic utilization of old ecosystems.

The effectiveness of studying all mentioned burials, in order to form a clear idea of the history of biogeocenoses, is made clear by the case of the steppes of the Russian plain. The study of steppe settlements of *Marmota bobac* and *Citellus pygmaeus* on the watershed meadows and bunchgrass steppes in the district shows that even in early Holocene there were well developed unsalted, but carbonified black soils. The leaching of carbonates from their horizon to the present-day level occurred gradually in the Middle and Late Holocene. This conclusion agrees well with the results of studies in the black soils buried beneath Bronze Age mounds and old fortifications of the Russian State (Modanov et al. 1967). The humus content of the black soil, during late glacier time, underwent comparatively small changes which attests to the shifts in the hydrothermal regimen in the steppe zone.

A characteristic feature of steppes is the humification of a large volume of vegetative remains owing to lavish spring-time humidation of upper soil layers. The humus substances which originated in the dry summer period are either fixed in the form of organo-mineral complexes or mineralized (Tyurin 1949, Aliyev 1966, Aleksandrova 1970, Ponomareva 1974, etc.). The relationship of the carbon of humic acids and non-hydrolized residue and the carbon of humic and fulvic acids depends on the intensity and the direction of the mentioned processes. With the increase in spring humidation and the reduction of the summer desiccation of soil, the hydrolythic decomposition of the vegetable remains increases and the formation of organo-mineral complexes and mineralization of humus substances become less intensive. The relation of humic acids to the non-hydrolized residue becomes broader, the proportion of humic and fulvic acids shifts to the latter, and there is an increase in the volume of the mobile fraction of humus substances.

The study of soil buried by marmots in the Middle Holocene in meadow steppes of the Russian plain has shown that humus formation was characteristic of large volumes of substances of the first fraction and an increased relation of humic acids to the non-hydrolized residue and of humic acids to fulvic acids (fig. 1). The combination of the mentioned signs testifies to intensive humification of vegetable remains, weak oxidation decomposition of humus substances, and the less intensive formation of organo-mineral complexes. The necessary condition for this is the moderate humidation and warmth throughout the spring-summer period.

The humus which was formed in meadow steppes at the beginning of late Holocene is distinguished by a low content of first fraction substances and a narrow relation of humic acids to the non-hydrolized residue and fulvic acids. For arid conditions, this reflects a

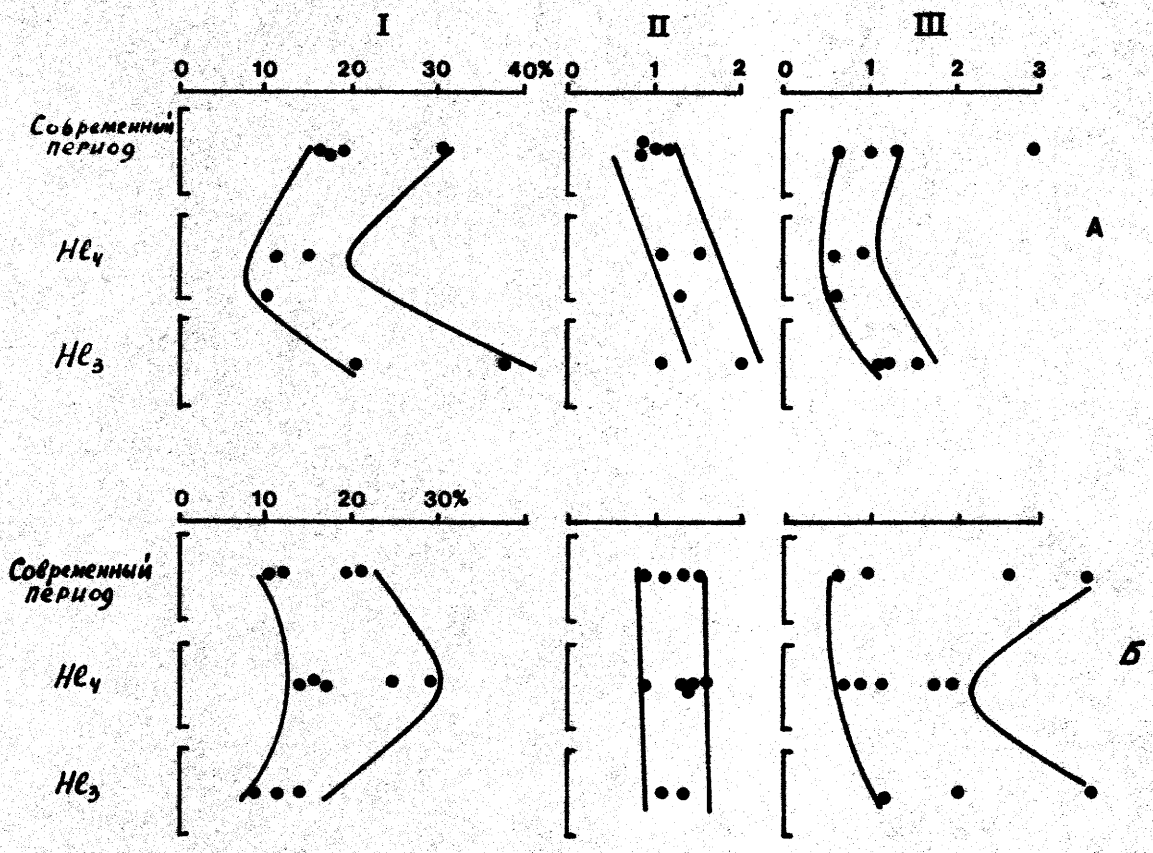

Figure 1.—Change in the humus composition of Holocene chernozyom. a—meadow steppes; b—forb-turf-vinous-cereal steppes. I. first fraction humus acids; II. $C_{h.acids}/C_{f.acids}$; III. $C_{h.acids}/C_{non-hydrolized\ remains}$.

typical arid condition--weakening of hydrolythic decomposition and humification of plant remains, with an increase in oxidation decomposition of the products.

In contemporary meadow-steppe humus, the number of mobile fractions and the relation of humic acids to the non-hydrolized residue increases again, while the relation of humic acids to fulvo acids decreases. The combination of these characteristics points to the substitution of a humid and moist period for an arid one.

The change in the hydrothermal regimen of the present-day steppes of the Russian plain was different. Judging by the composition of the buried humus, Middle Holocene was distinguished by a moderately warm and dry climate. The beginning of Late Holocene was characterized by increased spring humidation of the humus horizon and its strong and deep desiccation in summer. The contemporary climate of the present-day steppes of the Russian plain is very similar to that in the Middle Holocene.

Judging by the pollen spectrum of the humus horizons, buried by *Marmota* while building their burrows, grass associations prevailed throughout the postglacial period in the southern part of the

Russian plain. As for the relation of the Chenopodiaceae, Compositae, Gramineae and forbs of Early Holocene meadow and the forb-bunchgrass steppes, they were much alike. The taxonomic structure of the grass cover in meadow steppes, which took shape in Early Holocene, remained stable up to the present period. It changed radically in the forb-bunchgrass steppes in the beginning of the Late Holocene judging by a large reduction in the abundance of Compositae. This development lent the pollen spectrums of that type of vegetation its present-day character. Similar changes in the grass cover took place in the bunchgrass steppes of the Black Sea coast (table 1). A number of other peculiarities of the pollen spectrums give us grounds to believe that the reduction in

Table 1--Dominant components of pollen spectrums in the humus layers of the *Marmota bobak* and *Citellus pygmaeus* burrows[1/]

Formation time	Meadow	Forb-bunchgrass steppes	Black Sea coastal bunchgrass steppes
Modern	Chenopodiaceae Compositae[2/] Forbs	Chenopodiaceae Forbs	Chenopodiaceae Cyperaceae Gramineae Forbs
Beginning of late Holocene	Chenopodiaceae Compositae Forbs	Chenopodiaceae Forbs	
Middle Holocene	Chenopodiaceae Compositae Forbs	Chenopodiaceae Compositae Forbs	*Artemisia* Compositae Gramineae Forbs
Early Holocene	Chenopodiaceae Compositae Forbs	Chenopodiaceae Compositae Forbs	

[1/] The dominants of spectrums are the forms where pollen abundance is not less than 15%.

[2/] Compositae family includes all forms excepting *Artemisia*.

the abundance of the thistle family in presentday steppes was accompanied by an inhibition of grasses and an increase in the overall xerophytic character of the grass stand. The latter can hardly be explained by climatic conditions in the beginning of the Late Holocene. The humus content shows that there was increased spring humidation in that period and that it predetermined good vegetation of grasses and forbs. It may be noted, however, that the increase in xerophytism and the inhibition of grasses set in when there is pasture degradation of steppe grass stands (Lavrenko 1956). If the cause for the above-mentioned changes in the plant cover was pasture degradation, it had to be accompanied by an

increase in pasture weeds. The first signs of this, however, appear in pollen spectrums only by Middle Holocene. In Late Holocene and in the contemporary period, pasture weeds reach their maximal development. It is noteworthy that this event is preceded by an increase in legumes in the pollen profiles of the meadow and the forb-bunchgrass steppes. This also should be regarded as the result of pasture degradation. In the second stage of degradation, there is widespread development in the creeping plant forms which are poorly digested by cattle (fig. 2); the legume species play a noticeable role among the creeping forms (Kazanskaya 1965).

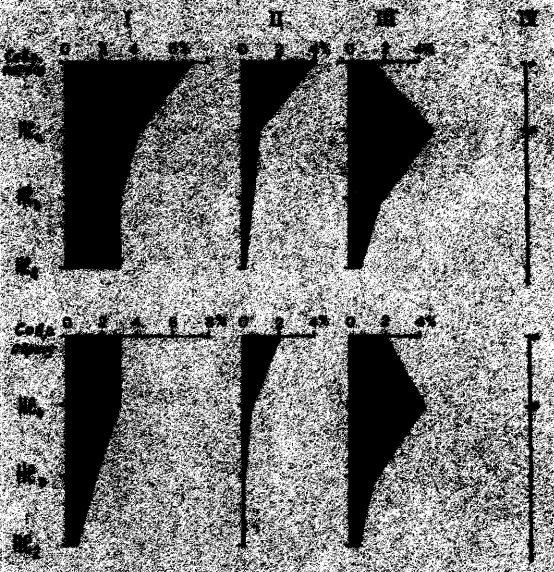

Figure 2.--Change in the amounts of pasture weeds and legumes in SUPCHINA palinological spectra. а--meadow steppes; б--(forb)-bunchgrass steppes. I. buckwheat (Polygonaceae), II. plantains (Plantaginaceae), III. legumes (Leguminosae), IV. amaranthaceae.

Judging by the taxonomic composition of bones buried in the burrows of the *Marmota bobak* and *Citellus pygmaeus*, vertebrates in the Early and Middle Holocene on watershed plains of meadow steppes were represented by the species of the steppe faunistic grouping — *Marmota bobak*, *Citellus*, blind rat-mole, common hamster, *Lagurus lagurus*, birch mouse, and the steppe polecat. They have survived without any particular changes to the present time in the virgin lands. The faunistic aspect was gradually changing in the forb-bunchgrass and the bunchgrass steppes, and by this time it has lost its Early Holocene aspect. The analysis of the factors which contributed to that change points to the climatic peculiarities of the post-glacial time and the pasture degradation of the plant cover which commenced in the first half of Late Holocene.

The great volume of pollen of pine and birch in the Early and Middle Holocene spectrums of the steppe marmot burrows (table 2) attest to the wide distribution of these species in ancient meadow and forb-bunchgrass steppes. Real forest biogeocenoses, however, did not exist at the time on the watershed plains. The latter circumstance is confirmed both by the composition of the pollen of grasses (table 1), (fig. 3) and

Table 2--Average pollen spectrums of marmot burrows in the meadow and forb-bunchgrass steppes

Spectrum formation time	Free pollen (percent)	Composition of tree pollen							
		Pine	Birch	Oak	Linden	Elm	Total broad-leaved pollen	Hazel	Alder
		Percent							
Meadow steppes									
Modern	22	68	27	4	2	0.5	6.5	7	7
Beginning of Late Holocene	18	82	14	1.6	1.2	.8	3.6	4	5
Middle Holocene	38	67	32	2	3.4	.2	5.6	5.5	6.4
Early Holocene	55	51	47	0	1.5	0	1.5	2	2
Forb-bunchgrass steppes									
Modern	7	79	16	1.3	.3	1.3	2.9	2.4	8
Beginning of Late Holocene	9	78	16	1.3	1.1	.6	3.0	1.4	6
Middle Holocene	26	85	11	.8	2	1.0	3.8	1.2	7
Early Holocene	14	91	6.5	.5	.5	.5	1.5	.5	7

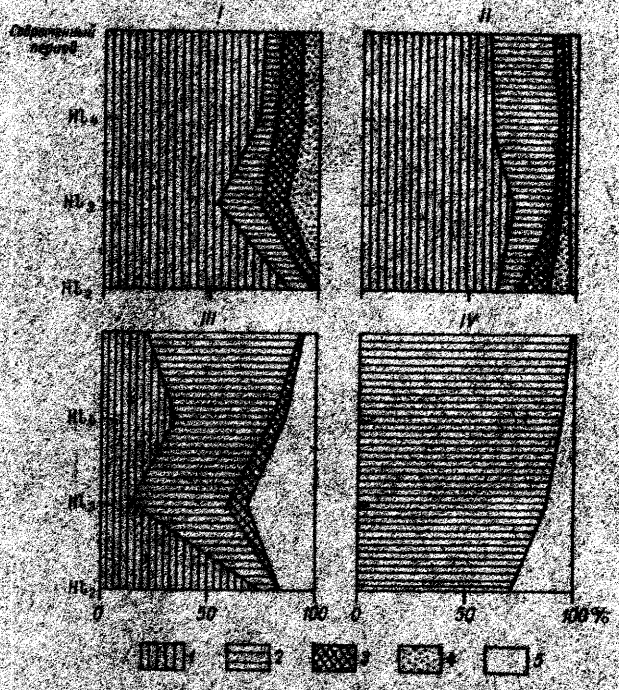

Figure 3.—Change in osteological aspects of steppe faunistic groupings of mammals: I, meadow steppes; II, forb-turf-fescue-cereal steppes; III, turf-fescue-cereal steppes; IV, wormwood-cereal steppes. 1, steppe marmot (*Marmota bobak*); 2, gophers (*Citellus*); 3, hamster (*Cricetus Cricetus*); 4, mole-rat (*Spalax microphthalmus*); 5, steppe lemming (*Lagurus lagurus*).

by the practically complete absence of bones belonging to the species of the forest faunistic grouping in the burrow burials (table 3). They began appearing there, in small numbers, only in the Middle Holocene which coincides in the time with the increase in the abundance of pollen of the broadleaved species in burrow horizons.

The information in table 3 demonstrates that the Middle Holocene maximum content of broadleaved species' pollen in burrow horizons is much weaker than in the low peat bog of the steppe zone. This proves that the real forest biogeocenosis in the Middle Holocene did not reach beyond steppe river valleys. Their spread is confirmed by the abundance of forest forms in the food of great

Table 3--Bones of secondary hosts and accidental visitors in burrows of steppe marmots

Bones of mammals	Time of bone burying			
	Early Holocene	Middle Holocene	Late Holocene	Modern time
Total including (%)	16	48	61	50
Steppe species	100	70	50	50
Forest species	0	7	16	24
Desert species	0	19	29	24
Widespread species	0	4	5	2

horned owls which nested along the beach cliffs. This has been established by A. V. Tattar (1958) during the study of cave deposits of the Upper Don.

The unfavorable climate in the beginning of Late Holocene did not alter the formation of forest biogeocenoses in river valleys. This is attested to by the abundance of species of the forest faunistic grouping in the food of the great horned owls which made their nests in river bank cliffs (Tattar 1958) and the increased frequency of the burials of its representatives in the burrows of steppe mammals (table 3).

Most likely the general reduction in tree pollen which is noted in the spectrums of the beginning of Late Holocene was the result of forest cuttings by man. An inevitable result of cutting tree stands in the arid climate of that time would be a clearcut trend of linden replacement by oak (table 2).

Forest vegetation in forb-bunchgrass steppes remained practically the same in the second half of Late Holocene. In the meadow steppe zone it reached watershed areas and covered a part of marmot settlements (Dinesman 1967). It should be noted that the recent appearance of forest on forest-steppe watersheds was identified by T. A. Serebryannaya and E. O. Ilves (1972, 1973, 1974). It is dated as the beginning of Late Holocene. Much earlier V. I. Bibikova (1963) studied osteological materials of archeological monuments of the Ukraine and concluded that the forest steppe of the Russian plain appeared only in Late Holocene on previously forest-free areas. It is easily seen that the results of studying the settlements of mammals, cave deposits, and peat bogs supplement one another and confirm this important conclusion.

The above materials develop trends of natural ecosystems and identify anthropogenic peculiarities in the structure. The approach should be applied to all the main types of the biogeocenotic cover. The historic description of the reference ecosystems of biosphere reserves should be viewed only as the first stage of this work. Owing to the peculiarities of the siting of paleoecological relics, it should be conducted throughout the territories of the regions of which the reserves are representative.

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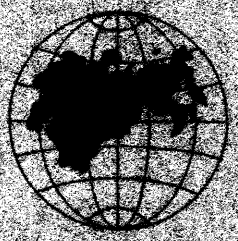

Remote Sensing in Arid Zone Biosphere Reserve Studies

by

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In our age of computers and spaceships, biosphere resources are being studied using modern technical systems. Remote sensing includes systems which produce valuable information about the landscape features (Kharin 1975). Remote sensors mounted on carriers (aircraft, helicopters, orbital stations, etc.) record reflected (or emitted) electromagnetic waves in different spectral bands. The final information can be obtained in various forms (photograph, photomap, digitized imagery, thematic map, etc.).

Let us first consider the special parameters of remote sensors, then the remote sensing techniques for the study of reserves. Aerial cameras are the main type of applied remote sensors. Aerial photography can be performed in the 270- to 980-nm spectrum band. The main Soviet camera model is the AFA-TE with focal lengths of 55, 70, 100, 140, and 200 mm, and an image size of 18 by 18 cm. There are also long-length cameras. The aerial cameras for desert lands have focal lengths of 100, 140, and 200 cm. Cameras with an image size of 18 by 18 cm and 23 by 23 cm are used in other countries as well as cameras with a small image size.

Various photographic emulsions are used for aerial photography. The panchromatic film sensitive to the visible spectral band is widely used. The infrared is another type of black-and-white film that should be mentioned. Color multi-emulsion films are divided into two types: natural and false color films. One of the latter types, the false color SN-6 film, is used by the Institute of Deserts. This film is used in the German Democratic Republic, Poland, Hungary, and other countries. Similar films in the United States of America are known as "camouflage detection" films.

Photographic systems are the common remote sensors used by investigators of the natural resources. They have a high resolving power; their geometrical properties allow aerial photography to be used for photogrammetric measurements and for compiling thematic maps.

Photographic films have, however, a disadvantage--their wide spectral sensitivity. An alternative method is to obtain the image in narrow spectral bands--multispectral photography. This method uses photographic films and a set of filters which cut off narrow spectral bands. Our investigations have shown that the most suitable zones for multispectral photography are: 400-525 nm

and 600-675 nm in sandy deserts, 600-675 nm and 750-850 nm in landscapes of Turkmenistan, and 400-500 nm and 620-680 nm in the foothills (Kharin 1974). The same result can be obtained by use of scanning systems.

As for the other types of remote sensors, mention should be made here of the infrared scanning systems. They register electromagnetic waves in atmospheric "infrared windows" (1.0-5.3 mkm and 7.0-14.0 mkm). Infrared thermography can be applied to the study of microclimatic phenomena, soil salinization processes in arid lands, and other problems.

The Institute of Deserts has carried out investigations on integrated mapping of the Badkhyz Reserve territory in Turkmenistan. The project has included spectral reflectance investigations, phenological observations, and thematic mapping. Based on these data and a survey of the literature, I propose a program of remote sensing for the study of the arid lands' reserves.

Table 1 lists a number of tasks which should be solved by remote sensing techniques. The main parameters of sensing devices are given as well. Let us consider them in detail.

1. *Compiling thematic maps.* These maps are needed for the normal functioning of reserves and they should cover the whole territory. The range of these maps should cover vegetation, landscape, geomorphology, and forest. Other types of maps, which are not mentioned here, should be compiled based on local conditions and needs.

Thematic maps should be compiled in scales of 1:10,000 to 1:25,000 with the same base map and projections. Map compilation must be performed using coordinated and mutually agreed methodological principles at the same time and scale. Fragments of two thematic maps of Kadkhyz Reserve area are shown in figures 1 and 2. One can see that the outlines of cartographic units (plant and soil association) coincide in many places, supporting the idea that *Pistacia vera* communities are confined to specific ecological conditions.

A set of thematic maps covering the territory of arid lands' reserves will provide investigators with very valuable information about natural conditions, areas, and spatial distribution of landscapes, degree of human influence, the influence of adjacent areas, etc.

2. *Studying the structure and biological productivity of biogeocenoses.* Aerial photographs covering large test areas in reserves should be used for this purpose. Large scale maps must be compiled for these areas.

Photographs at a scale of 1:2,000 and greater convey the image of all trees and shrubs, and large plants of other life forms are pictured as well. Some of the elements of plant cover can be

Table 1--Remote sensing for studying environmental conditions in reserves

Tasks	Carrier	Type of sensing					Scale
		Aerial photography			Multi-spectral scanning	Infrared thermo-graphy	
		Panchro-matic	Infrared	False color			
Compiling thematic maps	Aircraft	+		+	+		1:10,000-1:25,000
Studying the structure and productivity of biogeocenoses	Aircraft	+		+	+		1:2,000-1:5,000
Investigating microclimate	Aircraft				+	+	1:25,000
Studying the dynamics of natural phenomena	Space platform				+	+	1:500,000-1:1,000,000
Studying wildlife habitats	Aircraft	+				+	1:10,000-1:2,000
Studying the desertification process	Space platform				+	+	1:500,000-1:1,000,000
Investigating plant phenology	Space platform, aircraft	+		+			1:25,000
Preparing photo-interpretation keys	Aircraft	+					1:10,000-1:25,000
Visual reconnaissance (combined with selective aerial photography)	Aircraft, helicopter	+					1:1,000-1:2,000

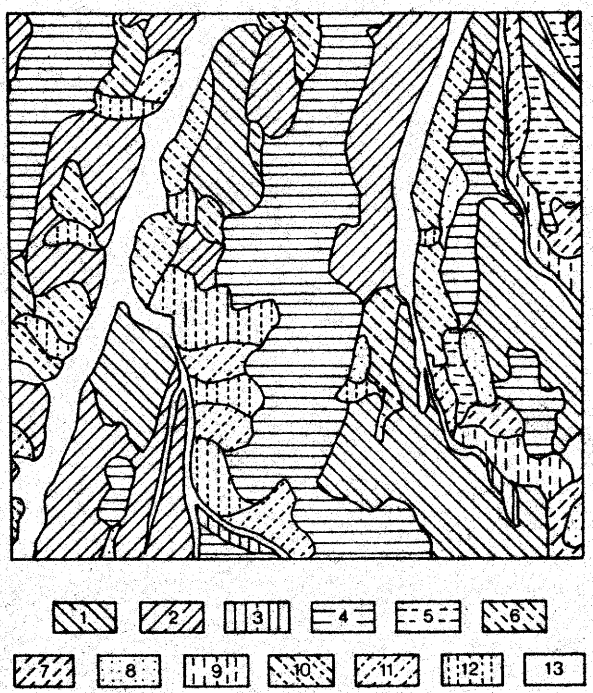

Figure 1.—Fragment of a soil map of the Badkhyz Reserve. 1, 2, 3, 4—Typical serozem soils on loess loam, confined to slopes of different exposition; 5, 6, 7, 8—serozem soils with weakly developed horizons, underlaid by sandstone, confined to slopes of different exposition; 9—abrupt sandstone slopes; 10, 11—weakly developed serozem soils underlaid by marl; 12—talus; 13—typical alluvial serozem soil.

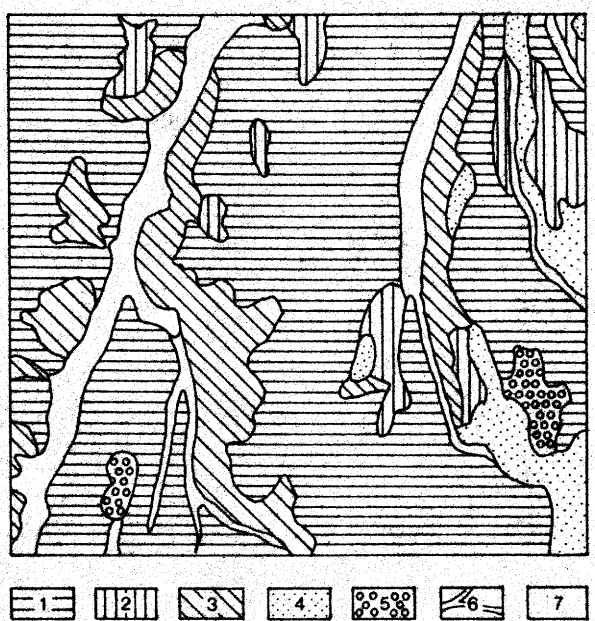

Figure 2.—Fragment of a vegetation map of the Badkhyz Reserve. 1—*Pistacia vera-Artemisia scoparia-Astragalus barrowianus*; 2—*Pistacia vera-Astragalus barrowianus-Onobrychis pulchella-Malcolmia turkestanica*; 3—*Pistacia vera-Cousinia congesta-Ferula badrakema*; 4—*Pistacia vera-Cousinia congesta*; 5—*Pistacia vera-Artemisia scoparia*; 6—*Pistacia vera-Onobrichis pulchella-Cousinia schistoptera*; 7—*Pistacia vera-Fremostachys labiosa-Cousinia schistoptera-Delphinium semibarbatum*.

measured on these photographs (height, crown diameter, density), others can be estimated by the regression technique. In this case the nonpictured elements are estimated from correlative dependencies with pictured elements. In this way the productivity of plant communities can be estimated.

Table 2 shows the relation between crown diameter of *Pistacia vera* (in meters) and the total volume of trees (in cubic decimeters). Crown diameter can be measured on aerial photos.

Table 2--Relation between crown diameter of *Pistacia vera* (DK) and total tree volume (V)

DK	V	DK	V
m	dm^3	m	dm^3
0.5	2.9	4.5	100
1.0	4.0	5.0	150
1.5	7.2	5.5	200
2.0	12.4	6.0	250
2.5	19.7	6.5	300
3.0	29.1	7.0	350
3.5	40.6	8.0	450
4.0	5.0	8.5	500

3. *Investigating microclimates.* In the study of bioclimatic features of a reserve territory, aircraft thermal imagery is useful. Murtha (1972) emphasized that the thermal image allows us to detect frost pockets and microclimatic features related to topography, moisture content, and other factors.

4. *Studying the dynamics of natural phenomena.* Periodic imagery from orbital stations and spaceships may yield valuable information on changes in vegetation cover, soil salinization, riverbeds, and wind and water erosion, etc. Depending on the intensity of these processes, the interval between surveys will vary from 5 to 10 years.

5. *Studying wildlife habitats.* Wild animals sometimes disturb the balance in nature, propagating themselves in great numbers on a reserve territory. Accordingly, current information on species composition, number of animals, forage, migration, etc., must be available to the reserve administration.

Direct counting of animals is performed on large scale serial photographs. Two methods are in practice: manual and automated counting. The latter technique is described by Bajzak (1974) for a waterfowl census. There are three stages: aerial photography, digitization of photographic images, and automated identification of number, species, and age of birds.

Aerial photographs of the scale of 1:10,000 permit us to study forage vegetation and disturbance, and drying up of plants. We can obtain information on forage yield.

Aerial photographs afford the possibility of compiling maps of vegetation damage caused by animals and insects and of estimating

their range by the disturbance they cause in the environment. Driscoll and Watson (1974) investigated, on large scale photographs, the range of dissemination of the pocket gopher (*Thomomys talpoides*), a small animal that may reduce herbage yields by 20% in some parts of North America.

6. *Studying the desertification process.* Desertification is taking place in many arid regions of the world. This process is a result of change in climatic factors in connection with man's activity which disturbs the balance of natural elements.

Remote sensing permits us to study this process on a global scale and at the regional level. Space photos are useful for the study of desertification. Otterman (1974) published interesting information about desertification in the Sinai and Negev deserts. He used images obtained by the American satellite ERTS-1. Areas covered with desert vegetation contrasted with those devoid of vegetation. Areas without vegetation cover were "thermal depressions" with a cooler surface. The rate of precipitation was lower here resulting in desertification. The process was of a cyclic character.

Regional changes in natural conditions can be detected on aerial photos of different scales. Usually, any change in the landscape's appearance, resulting in an optical contrast with the surrounding terrain, is pictured in the photos of a given scale.

7. *Investigating plant phenology.* Phenology of plants in U.S.S.R. reserves is observed made regularly, and calendars of seasonal events are being compiled. These data are of great scientific and practical importance. The three main directions in phenological investigations should be mentioned.

(a) *Systematic observations.* The Institute of Deserts has elaborated a method of phenological observations known as "mathematical phenology." As a result of observations, a phenological distribution series is obtained; this set of observations can be analyzed by standard statistical methods. As an example of this technique, table 3 shows the results of spring phenological observations in the Badkhyz Reserve in 1973 (Kharin and Kiriltseva 1975).

(b) *Phenological mapping.* Using mathematical phenology and false-color photographs, we compiled a set of phenological maps which cover the territory of the Badkhyz Reserve. A fragment of such a map (of *Pistacia vera* phenology) is given in figure 3. The map covers the same area shown in figures 1 and 2.

(c) *Periodic surveys from aircraft or orbital stations.* Photographs may yield valuable information on seasonal changes in appearance of landscape in arid zone reserves. Compilation of zoophenological maps is also of great interest, but adequate methods for compiling such maps have not yet been developed. Remote sensing techniques offer the possibility of developing this capability in the future.

Table 3.--Percent of *Pistacia vera* trees in various spring phenological phases in the Badkhyz Reserve in April, 1973

Phenophase	Sample plot	Date							All
		April 5	April 8	April 11	April 14	April 17	April 20	April 23	
Pollen formation (male trees)	1	20	20	12	11	10	8	11	100
	2	0	30	32	25	13	0	0	100
	3	31	28	18	10	13	0	0	100
Leaf bud burst	1	0	10	18	25	12	12	5	100
	2	0	3	9	18	43	20	7	100
	3	0	20	19	17	23	21	0	100
Flower opening (female trees)	1	0	12	13	15	19	22	19	100
	2	0	0	0	20	45	23	12	100
	3	0	6	6	10	58	20	0	100
Coming into leaf	1	0	0	7	16	27	37	13	100
	2	0	0	0	0	15	50	35	100
	3	0	0	0	9	28	45	18	100
Ovary formation	1	0	0	0	6	14	44	37	100
	2	0	0	0	6	10	40	50	100
	3	0	0	0	0	13	38	39	100

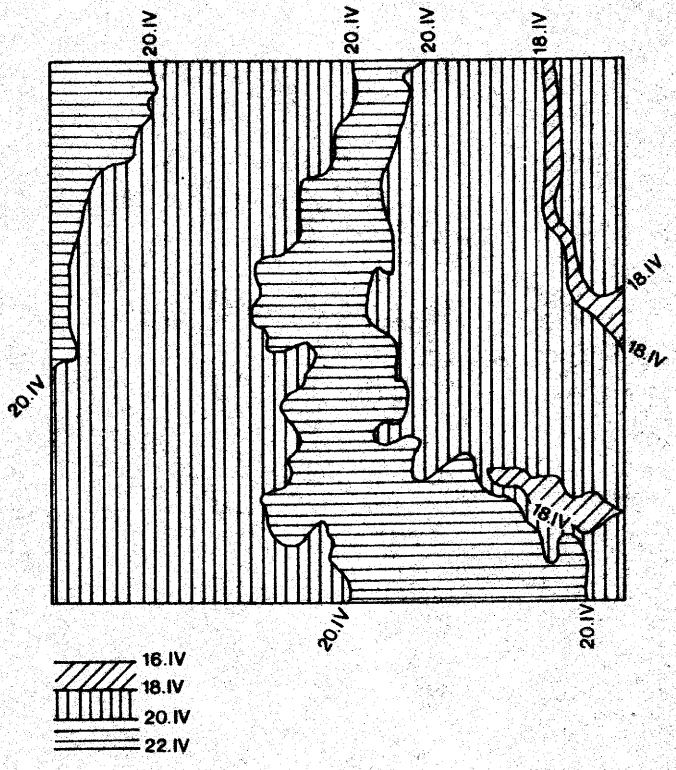

Figure 3.—Phenological map fragment showing percent of *Pistacia vera* coming into leaf on the Badkhyz Reserve.

The frequency with which imagery is obtained in phenological investigations may vary. In the spring it may be 10 to 20 days; in summer, 1 to 2 months. Phenological information in forms a, b, and c, mentioned above, is useful for the normal utilization of arid zone reserves. Maps of phenological events are necessary, for example, for the estimation of forage plant yields, in order to optimize the number of animals, etc.

8. *Preparing photo-interpretation keys.* Reserves and National Parks with typical landscapes and nature monuments should be conserved as virgin lands for future generations. These areas should be photographed from the air, to provide documented evidence of the state of the landscape's appearance. In our opinion, the preparation of a set of reference photographs of these areas is a timely undertaking. These key photographs must be periodically retaken and, together with earlier photographs, kept at reserve offices or at national centers. Modern electronic techniques allow us to keep that information in any suitable form including digitized imagery and electro-magnetic tape recordings.

9. *Visual reconnaissance.* In the daily work of reserve administration, reconnaissance from aircraft or helicopter is a rapid method of obtaining information. In the Badkhyz Reserve,

for example, the administration periodically takes the census of kulan (*Equus hemionus*) and other wild animals by helicopter. By visual reconnaissance we can also accomplish other tasks (phenological observations, fire control, study of wild animal migration, etc.).

It would be very useful for the aerial observer on board a helicopter or aircraft to have a hand-held camera to take pictures of interesting objects and phenomena. The aircraft or helicopter can be equipped with an aerial camera with a small-size image. These pictures can be taken without special equipment.

These, in our opinion, are the main tasks which may be accomplished by investigating natural conditions of reserves using remote sensing. Special funds should be provided for this work, because it would otherwise be impossible to obtain aerial and space imagery. The financial problem may be solved in different ways, such as: a. In the framework of international projects, like Earth Resources Technology Satellite (ERTS), Soyuz-Apollo, etc. (In these cases, photographs of reserves will be obtained without allocating special funds.); b. On the basis of National projects, when aircraft or orbital photos may be obtained through small additional funds; c. By allocating special funds for research in reserves. In particular, our work on mapping the Badkhyz Reserve territory was organized using special funds.

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Integrated Studies at the Pushchino Biosphere Station

by

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The establishment of a network of biosphere stations and a global environment monitoring system is one of the finest international collaborations for the sake of man's health and well-being.

The human race is alarmed by the results of its own actions and by the possible consequences of these actions which threaten man's health and well-being. The progress of science and technology has made the anthropogenic factor, by virtue of its end results, comparable to natural factors. Tremendous volumes of industrial waste not only alter the chemical composition of water, atmosphere, and food but materially influence the climate, the circulation of substances and energy in ecosystems, and inhibit biological processes. Nature is no longer capable of coping with the volume of foreign chemical compounds which pollute the atmosphere, water, and soil. We see a noticeable decrease in the self-cleaning ability of the environment. The ecological equilibrium is being disrupted and is becoming unstable.

Mankind is already expending considerable funds to decrease the volume of waste and to diminish the level of environmental pollution. Numerous purification plants are being established as well as closed-cycle industries; their effectiveness, however, is insignificant and they fail to offset the mounting contamination of the biosphere.

Mankind has to admit that it was unprepared for the problem of protecting the environment against anthropogenic contamination. Thus far, there is no conceptualization of the normal state of the biosphere components--quantitative determinations of its background state or of the permissible range in variability; the scope of observation is inadequate. A number of countries have started to monitor environmental quality, but the techniques of collecting and interpreting the resulting data differ greatly from country to country and, for all practical purposes, lack comparability. The task of protecting the biosphere, however, has transcended the national framework, since migrational processes and the concentration and detoxication of biosphere pollutants are developments of a global character. Effective control of biosphere pollution is unthinkable without pooling world resources.

The need for objective information about the level of contamination of the biosphere as a whole gave rise to the idea of

establishing an international network of monitoring stations on the state of biosphere components. The stations should use the same techniques and their concurrent work should produce integrated information on the level of contamination in background locales which are comparatively remote from sources of intensive contamination.

The idea of natural zonality has been taken as the basis for siting the stations over the world's surface, since every natural zone is governed by its own laws of the circulation of substances and energy. The stations should be located in areas with economies typical for the given zone and typical utilization of natural resources.

The tasks of biopshere stations should not be confined merely to observation over the contamination level. Another important function should be research and experimentation on distributal patterns of contaminants, their concentration and detoxication at various points in the ecosystem, biotic responses of the biota to different contaminants, identification of pollutant indicator organisms, etc.

An objective analysis and appraisal of the findings assumes the ability to distinguish changes in the biosphere taking place in the process of evolution from changes produced by anthropogenic influences. The objects of observation at biosphere stations, therefore, should be not only natural ecosystems uninfluenced by man (reserves) but also ecosystems undergoing different stages of economic development. Therefore, the selection of sites for biosphere stations should be based on the idea of having a sufficiently large area capable of encompassing, within the given natural zone, at least three types of territories: (1) a territory free of economic utilization and, to preserve the gene pool, protected against man's intervention--the Reserve territory; (2) a territory with a typical natural landscape subject to man's minor influence; (3) a territory which has been intensively exploited by agriculture or forestry, e.g., cultivated landscapes. The territories which are intensively used by industry, construction, etc. belong to the sphere of impact monitoring (local monitoring).

The Pushchino Biosphere Station is being established in a typical Central Russian landscape. It is using the facilities of the Biological Research Centre of the U.S.S.R. Academy of Sciences in Pushchino (Moscow region). The plan is to arrange observation points on the territory of four land-users: (1) the Prioksko-Terrace State Reserve; (2) the "Russky Les" experimental-production forest economy association, whose facilities will be used to establish the national park of Central Russia; (3) the fields of the "Bolshevik" state farm which is a pesticide testing center; and, (4) the territory of the experimental field station of the Institute of Agrochemistry and Soil Science of the U.S.S.R. Academy of Sciences - a place of experimentation on melioration and agrochemistry.

The overall station territory will comprise approximately 100 000 hectares, most of it in natural forest tracts. The area of the Prioksko-Terrace Reserve is fully withdrawn from economic utilization. The minimum of forest management measures (selective and sanitary cuttings) is conducted in the forest tracts of the "Russky Les" association. Experimental application of fertilizers, pesticides, and irrigation is conducted on the fields of the experimental field station of the Institute of Agrochemistry and Soil Science of the U.S.S.R. Academy of Sciences and at the "Bolshevik" state farm.

Thus, we are in a position to carry out observation over the background state of natural ecosystems and follow the changes caused by anthropogenic influences. Besides, this, we shall study small town influences on the environment (Pushchino and Serpukhov). Large cities and industrial centers - Moscow, Vladimir, Riazan, Tula, Kaluga - are all more than 100 km away. The Oka River, which flows across the relevant territory, has not been regulated and therefore is conducive to hydrological and hydrochemical studies on a comparatively large waterway.

A number of biological objects (flora and fauna) have been observed for 20 years on the territory of the Prioksko-Terrace Reserve. The identification of lime sequences of nature development is extremely valuable. No less important is the fact that the zones of grey forest soils and sod-podzolic soils have analogs in other countries, which makes it possible to compare the results on the background state of biosphere components at several stations.

The methodology of monitoring at a biosphere station should be based on an integrated biogeocenological approach to the study of natural objects in their entity and relationships. We have done this via our research thanks to the efforts of the distinguished Russian scientists V. I. Vernadsky, B. B. Polynov, and V. N. Sukachev.

In our opinion, the main tasks in starting a biosphere station are: (1) selection of the sites for observation points (biosphere pickets) and organizing the territory; (2) codification of biosphere pickets, collection of information on the initial state of the component of the biogeocenosis (zero cycle); (3) collection and consolidation of available data on the past state of the biosphere components on the controlled territory; (4) organization of the monitoring and corresponding analytical studies; (5) identification of storage places and the development of files (subsequently a museum) of dated specimens of native objects collected in the past on the territory of the controlled region; (6) development of computerized techniques of initial data coding, storage, and processing, and; (7) formulation of "biological monitoring" principles.

Naturally, the global monitoring system will actually begin with the establishment of regular, simultaneous observations on carefully selected sites using standard techniques and identical instruments. This will, however, take time. There is still no agreed-upon program of observation. Observation techniques and

instruments differ greatly and, at times, are incomparable even on a national level. There is no uniform system of instruments adequate for the tasks, and there are many theoretical ambiguities.

Furthermore, much time will pass between the commencement of system operation and the objective appraisal of its findings. It will take even more time before we shall be in a position to offer a real forecast of changes in the biosphere for a more or less significant time sequence.

Nevertheless, the present situation calls for effective action. The task is set most specifically. To wait for the development and adoption of a uniform technique, invention, adoption, and adequate manufacture of the necessary instruments and automatic systems of observation which satisfy the requirements of the monitoring program is to waste time and indefinitely delay the appraisal of the state of the biosphere and determination of its development trends.

The indicated program can be accelerated under present-day conditions if we take advantage of the following three important factors.

(1) Inasmuch as most of the planned biosphere stations are located in places where different establishments are already conducting integrated studies and there is a definite range of observations in a time sequence, it is necessary to continue the goal-oriented studies using the available resources, ways, and means - namely the state and changes in environment by the largest possible range of parameters, gradually approximating the desired level. We believe that, in this case, the most fruitful direction of research is the balance approach (the balance of organic substances in ecosystems, the balance of biophyllic elements, the hydro and thermal balance, etc.).

The positive significance of these studies at the preparatory stage of the establishment of a global-monitoring system is not only the collection of data on the state of environment, but also the formation and training of groups of different specialists. Such groups are capable of joint-integrated studies and can produce summarized functional information on the relationships of biosphere components. They can also conduct experiments to identify the regularities of migration, concentration, and detoxication of pollutants in the biosphere and in its components.

(2) Numerous cartographic data, texts, and figures on the state of natural components and man's economic activity at different periods of history are scattered in literature and in various archives. The concentration, processing, and tabulation of this information on a regional level might provide necessary data about the changes in the region's nature, resulting from both evolution and anthropogenous influences. Banks of a biosphere station, should be organized mainly along two lines: (a) stages of natural evolution, and; (b) stages of economic development of the region.

(3) There are a large number of natural exhibits (specimens of soil, rock, peat, trees, herbariums, animals, insects, archaeological material, etc.) at regional museums of history and local studies, at museums of schools and research establishments, and in private collections. All of them were collected in definite places at different periods of time. Organization of a regional collection of dated specimens and their subsequent chemical analysis, in chronological order, offers another chance of obtaining a time series aimed at identifying the trends of contamination up to the present time. This work, however, requires considerable effort and resources. Besides this, considerable prudence should be exercised, since this concerns unique exhibits of historical importance. In our region, we have already discovered herbariums, soil specimens, stuffed animals, and collections of insects dating to different periods.

The chemical analysis of natural objects and the quantitative determination of pollutants is not the final research stage. Other important aspects are the reaction of living organisms, their associations and ecosystems as a whole, to the level of specific pollution, the identification of the biological effect of pollution, the identification of organism-indicators of pollution, and determination of types of reaction of different organisms to different pollutants. This is a complex task, especially if we take into consideration the necessity of strictly distinguishing the changes caused by evolution from those by pollution.

The reaction of living animals to environmental changes and to pollution can be evaluated by the changes in the numbers, composition, biomass, physiological functions, migration, activity, life span, and morphology. It happened, for instance, that there has been a considerable drop in the number of ordinary earthworms in our region in recent decades. The causes of this have yet to be determined in the context of the entire program.

For a complete picture of the situation, we should have a full inventory of all sources of contamination of soil, water, and atmosphere in the territory of the region and we should determine the range of the influence of the contaminants.

All this information can be collected and processed before the global-monitoring system is fully launched and even parallel the global-monitoring system in the first years of observation. This "step back into the past" will make it possible for valid forecasting, even in the initial period of the functioning of the system, of possible changes in the biosphere during a definite period of time and elucidate the main development trends caused by man's influence.

The central task during the preparatory period of the organization of the biosphere station in Pushchino is the establishment of an observation and analytical complex. Many subdivisions of the Institute of Agrochemistry and Soil Science, the associates of the Prioksko-Terrace Reserve, Moscow University, the Hydrometeorological Service, and other concerned establishments have been drawn to this work.

For the first stage, we have chosen five permanent biosphere sites. Three of them are in natural biogeocenoses--an oak wood, a pine wood, a forest glade--two are on agricultural land, e.g., non-irrigated ploughland at a watershed and on irrigated floodland of the Oka River.

Though the studies are conducted concurrently and in an integrated manner, we have subdivided the objects and parameters of studies for greater clarity.

OBJECTS AND PARAMETERS OF OBSERVATION

Objects:

ATMOSPHERE: (1) elements of the microclimate (radiation, thermal water balance, variations of the climate in time and space);
(2) total contamination of the atmosphere including dust content;
(3) chemical composition of pollutants (dust, liquid and solid atmospheric fallout);
(4) pollution of the atmosphere and photosynthesis;
(5) gases: CO_2, CO, O_2, O_3, SO_2/H_2S, NO_x.

WATER: (1) rivers, lakes, marshes, temporary streams, puddles;
(2) ground water (depth);
(3) soil solutions;

Parameters (1) water regimen
(2) general contamination
(3) organic substances
(4) biophyllic elements
(5) heavy metal and trace elements
(6) organochlorides (DDT, PCB).

SOILS: (1) Morphology, chemical composition, physical state;
(2) Soil regimens: (a) moisture, (b) temperature, (c) soil-air composition (CO_2, O_2), (d) salt composition, pH, Eh, Fe, Ca, Mg, (e) organic content, (f) heavy metals, (g) trace elements, (h) absorbed toxicants.
(3) Soil solutions - SO_4, Cl, NO_3, biophyllic elements, heavy metals, trace elements, organic substances.
(4) Humus and its forms.

BIOTA: (1) Surface and subsurface phytomass; temporal-spatial structure and annual dynamics of its amount and chemical composition; the dependence of photosynthesis upon the extent of atmospheric contamination.
(2) Fauna; dynamics in time and space, activity (specifically of invertebrates).

(3) Microflora: time and space dynamics of the composition, number, and activity.
(4) Farm animals: number, mass, productivity, geographical distribution.

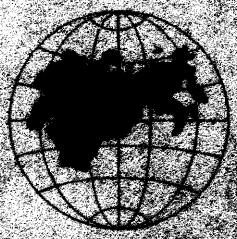
FOOD:
(1) Harvest of farm plants, quality, caloric content, protein content.
(2) Chemical compositon of food of plant and animal origin (extent of contamination).
(3) Analysis of feeds and additional mineral feeds for animals consumed by man.

LOCAL CONDITIONS: Diseases of man, animals, and plants subject to analysis in time and space (life span, population density, number, birth and death rate, etc.).

Besides creating an observation complex for the period, we also plan a series of studies related to establishing a data bank at the biosphere station: (1) the compilation of a regional atlas on "Biosphere Resources"; (2) the compilation of regional catalogue of data characterizing the state of biosphere components at different time periods; (3) the compilation of a data catalogue and an atlas of the region's history of economic development; (4) the compilation of a data catalogue on biotic reactions to changes in the environment and anthropogenic contamination; (5) accidental verification of biota's reaction to the character and level of contamination; (6) the compilation of a catalogue of storage places for dated specimens, collected at different time periods in the region in order to set up a regional collection and provide for subsequent analyses.

In order to fulfill these objectives, the Institute of Agrochemistry and Soil Science of the U.S.S.R. Academy of Sciences established a Division for Ecological-Biosphere Research which incorporates five subdivisions, including: Laboratory of Bioproductivity of Landscapes, Laboratory of Modeling Soil Processes, Laboratory of Migration and Metabolism of Herbicides, a branch of scientific data storage and an independent structural unit - "Biosphere Station".

Besides this, to fulfill the field program the Institute established an ecological-biosphere team which will incorporate the associates from most of the subdivisions of the Institute and from the Prioksko-Terrace Reserve, undergraduates and members of the faculty of Moscow University and of Moscow Forest Industry Institute and personnel from other establishments - an entire contingent of specialists capable of ensuring fulfilment of the entire range of studies stipulated by the program.



Integrated Monitoring of Environmental Pollution at Biosphere Reserves (Organization and Methods)

by

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INTRODUCTION

Man's impact on the environment has increased sharply in recent decades. The volume of gaseous, liquid, and solid waste discharged into the environment has become comparable with the volumes of matter transferred in the course of natural events. The consequences are particularly dangerous when the environment is polluted with substances which are alien to nature and whose natural processing is impossible.

The concentration of pollutants in ambient air, in natural waters, soil, and in the biota (including man) may reach levels where unfavorable changes in the ecosystems or in their components should be expected, including changes in climate.

In order to distinguish anthropogenic changes against the background of natural processes, special observations should be conducted on the state of the biosphere. The main objective of these investigations should be information about the initial state of the environment, its present level of contamination, paths and rates of global dispersion of pollutants, and directions of change in environmental quality. This information is needed to understand the basic physico-chemical and biological processes and to expand our knowledge about the influence of pollutants on biological systems and the biosphere as a whole. This is necessary in order to draft recommendations for optimal and global environmental control.

A system of biosphere reserves is being established to study, control, and forecast the state of anthropogenic changes in the biosphere. This system should be a component of national monitoring of environmental conditions.

The biosphere reserve system (BRS) presupposes a set of purposeful, systematic observations of environmental elements or indicators of its state; the observations are carried out in keeping with a definite program, employing comparable methodology of collecting and analyzing the data about environment. The network of biosphere reserves should be representative of the main biomes of our planet.

The main tasks which should be resolved by this system, with the help of conventional and new services, are the following: (a) observation of changes in the state of the biosphere and identification of changes caused by man's activity; (b) forecasting and determination of trends in biosphere changes; and (c) appraisal of changes and trends of changes in the biosphere.

The settlement of these tasks will help elaborate recommendations for prevention of undesirable consequences, and optimizing man-environment relationships.

An essential principle of establishing a biosphere reserve system should be ensuring the integrated character of observation including all the main pollutants in all media, all the essential elements of the biosphere, and the accompanying factors which make easier the interpretation of the findings. This integrated approach is particularly suitable for determining and forecasting the overall biosphere condition. Primarily, this relates to the necessity of developing methods of biological monitoring as one of the most essential, but least developed types of monitoring.

The organization of the biosphere reserve system should provide for observations in keeping with a program that incorporates all priority pollutants recommended at the Intergovernmental Council on Monitoring in Nairobi (1974). Some additional pollutants in different media should be included as well as other elements of the environment which might be of interest (at present or in the future) from the point of view of an integrated appraisal of the state of the biosphere.

To identify the trends in biosphere conditions and to develop a forecast, we should have information on the past state of the biosphere. The possibility of new tasks, techniques, and instruments for studying the state of the biosphere makes necessary the development of means of preserving the specimens taken at the present time and techniques of their durable storage.

The present report discusses pollution monitoring programs designed for biosphere reserves in the Soviet Union. The following approach to monitoring refers mainly to dry-land biosphere reserves, although there could be little difficulty in developing a program of observation for marine biosphere reserves. The fact that bodies of water exist within dry-land reserves allows for considerable expansion of a program of observation, making it more comprehensive.

MONITORING THE CHANGES IN THE STATE OF THE BIOSPHERE

The environmental monitoring program should cover three main fields of research:

1. Geophysical parameters of the environment:

(a) measuring solar radiation as the energy base of all biosphere processes. This necessitates an organization of actinometric observation on the territory of biosphere reserves, i.e., measuring solar radiation intensity (direct, scattered, and total), the radiation balance, and the albedo. Integral indicators of dust content in the atmosphere, turbidity factor, etc, may be obtained by way of spectral measurements of direct and scattered solar radiation;

(b) identification of the influence of temperature of anthropogenic origin on biosphere's overall energy by measuring air temperature in time and space (the vertical aspect). These measurements are a component of weather observations;

(c) meteorological monitoring in the near-the-earth layer (up to 15-20 m) and in the boundary layer (aerological monitoring) to cover temperature and air humidity, wind velocity and direction, atmospheric pressure, longitudinal and vertical components of the wind velocity, pulsation, and atmospheric precipitation;

(d) hydrological observations recording variations in level, average rate, and total discharge of rivers, granulometric composition of suspended particles and bottom sediment, river bed processes, etc., i.e., the parameters which describe the water and thermal balances of rivers and other reservoirs and the specific features of their regimen.

The observations listed under points (a) through (d) can be carried out in the framework of national weather services (or the World Meteorological Organization) using standard techniques and equipment and, therefore, do not present any fundamental difficulties. It is possible that the time or frequency of observation will have to be altered to meet the needs of an integrated study of environmental conditions.

2. Observations on the chemical composition (of natural and human origin) of the atmosphere, precipitation, surface waters, soil, bottom sediments and the biota.

To perform this set of observations, a list of the most important pollutants of anthropogenic origin must first be compiled. The criteria for selecting these priority pollutants include factors such as spread, persistence, possibility of conveyance along alimentary chains and the accumulation in humans, toxicity, and potential for transformation into more dangerous chemical compounds.

The following contaminants should be monitored in accordance with these criteria in the observation program on biosphere reserves:

I. Ambient air
1. Sulfur dioxide
2. Suspended particles (aerosols)
3. Carbon dioxide
4. Nitrogen oxides (nitric oxide and nitrogen dioxide)
5. Ozone
6. Carbon monoxide

7. Reactive hydrocarbons
8. Lead, mercury, arsenic, and cadmium content of aerosols and, possibly, the content of sodium and chlorine ions.

II. Atmospheric fallout
1. DDT and other chlororganic compounds (PC), lead, mercury, arsenic, and cadmium.
2. All anions and cations recommended for determination at WMO observation stations (sulphates, nitrates, chlorides, ions of ammonium, calcium, etc., electroconductivity, pH, and biogenic elements).

III. Water
1. Mercury (including methyl mercury), lead, arsenic, and cadmium.
2. DDT and PCB, biogenic elements.
3. Petroleum products (marine areas).

IV. Soil
1. Mercury, lead, arsenic, cadmium, DDT, and PCB.

V. Biota (agricultural crops, grasses, etc.)
1. Lead, mercury, arsenic, cadmium, DDT, and PCB.
2. Biological monitoring.

Biological monitoring should have an important place in the biological reserve system. To a certain extent, it is represented in the above list by the determination of DDT and other chlororganic compounds and also of metals in farm crops, grasses, and other representatives of the biota.

As for water subjects, it is more expedient to include the studies of hydrobiological indicators in biological monitoring.

It should be emphasized that the important thing is not only to study the accumulation of different pollutants in biological objects but also to identify their biological and ecological effects. Special attention should be drawn to this type of monitoring owing to its importance and scanty information.

It is of interest to preserve special specimens for a long time for their subsequent analysis. The relevant motivation is that in the future we may want to study pollutants which are currently unrecognized or considered unimportant at present. It is also possible that more powerful analytical techniques and instruments will appear in the future making additional analyses desirable. Development of techniques of conserving the specimens for durable storage and the development of banks of such specimens might be another important task of monitoring.

TECHNIQUES AND INSTRUMENTS FOR THE BRS

The main peculiarity in analyzing pollutants in the biosphere reserve system is their extremely low levels in the studied objects,

on the one hand, and simultaneous presence in specimens of accompanying pollutants and natural compounds which are liable to interfere with proper analyses on the other hand. Under such circumstances high sensitivity and the specific tests may be achieved in most cases by enriching the specimens and by using more refined physico-chemical techniques and instruments.

It should be noted that the techniques, specifically elaborated for determining background concentrations of pollutants, are nonexistent in many cases. Therefore, a great deal of work will have to be carried out to determine the possibility of using techniques initially designed for testing higher levels of pollution. Development of standard and reference specimens has an important part in ensuring the unity and the correctness of measurements along with comparable international technique and instrument testing.

Sulfur Dioxide

Not one of the presently known standard automatic instruments can be used for determining background concentrations of sulfur dioxide (~1 mkg/m^3). In the first stage of observation at biosphere reserves, it will most likely be necessary to use one of the manual methods recommended by the World Meteorological Organization WMO (for instance, the West-Gaek technique).

Ozone

Background concentrations of ozone may vary from several to 100-200 mkg/m^3; there are automatic gas analyzers for measuring such concentrations. These instruments are constructed on different principles. The best among them is, most likely, the analyzer based on chemoluminescence which develops in ozone - ethylene reactions.

Nitrogen Oxide

Background values of nitrogen dioxide may vary from 0.4 to 10 mkg/m^3, nitric oxides--by less than 6 mkg/m^3, the reliable determination of such low concentrations is not yet completely solved.

Carbon Monoxide

The necessary accuracy of carbon monoxide determinations (± 0.2 ppm when the measuring value approximate 320 ppm) may be achieved by automatic analyzers which are based on nondispersion infrared spectrophotometry. Background concentrations of carbon monoxide on the order of 0.1 mg/m3 may be measured, for instance, by the gas chromatographic technique in which carbon monoxide is reduced to methane (nickel being the catalyst) and recorded in a flame-ionization detector.

Reactional Hydrocarbons

Their low background concentrations (less than 10 mkg/m^3) requires the use of automatic gas chromatographs with a sensitivity of not less than 5 mkg/m^3.

To determine the level of suspended particles and atmospheric precipitation, the standard techniques recommended by the WMO are suitable.

A more complex task is the determination of lead, mercury, arsenic, and cadmium in particles and sediment of toxic metals owing to the background content of these metals in filters and other materials. As for techniques of determinating these metals, a combination of neutrono-activization, atomic-absorption, and spectrophotometric methods make it possible to resolve all relevant tasks.

DDT and PCB

DDT and PCB are determined, with sufficient reliability, by means of gas-liquid chromatography. For background monitoring it is necessary to provide for concentration and separate determination of these substances.

Petroleum Products

The presence of these products in natural (marine) waters might be determined by a variety of techniques, but the most sensitive is the one based on the application of infrared absorption of CH-, CH_2- and CH_3-groups.

In conclusion, it is necessary to mention that the organization and techniques of monitoring environmental pollution at biosphere reserves is a difficult scientific and engineering problem and requires broad international collaboration.

Characteristics of Soviet BIOSPHERE RESERVES

San Joaquin Experimental Range

Olympic National Park

APPENDIX

THE CAUCASUS BIOSPHERE RESERVE

The reserve is located in the western part of the Caucasus mountain range in the square 39°40' to 40°30' northern latitude and 43°30' to 44°0.5' eastern longitude in the Krasnodar and Stravropol regions of the Russian Soviet Federated Socialist Republic (RSFSR). The yew-box tree grove, district of the settlement Khost, city Sochi, and the Sochi Forest Park are separated from the basic territory of the reserve. The geography of the reserve varies from the lowlands close to sea level to the mountain peaks of the main Caucasus mountain range at altitudes of 3 360 m. The territory of the reserve is 263 500 ha and consists of a typical mountain landscape. The main Caucasus mountain range and Peredovoj, located to the north of the main range, form the basis of the reserve's relief.

A united reserve territory exists in correspondence with the statute covering the Caucasus State Reserve. A reserve buffer zone is currently being created.

Flora

The flora of the reserve reflects the complex formation history of the present western Caucasus surface and the considerable variation in relief and in climate. The flora includes over 1,500 species of higher plants. The flora probably includes more than 3,000 species if the varieties of mosses, fungi, lichens and algae are added. The number of trees and shrubs--165 species--is large. Endemic plants amount to about 20 percent of the total number. Tertiary relict plants are preserved in the reserve. They are representatives of the ancient preglacial flora of the Caucasus: Caucasus fir (*Abies nordmaniana*), eastern beech (*Fagus orientalis*), chestnut (*Castanea sativa*), eastern spruce (*Picea orientalis*), Iberian oak (*Quercus iberica*), sycamore (*Acer pseudoplatanus*), Caucasus linden tree (*Tilia caucasica*), and others. A large part of the reserve is covered by forests. Broadleaf forests grow up to 1 200 to 1 300 m in the mountain belt. Oak forests can be found on the bright southern aspects at altitudes of 800 to 900 m. Beech forests are common and often cover the entire southern slope of the main range from 500 m up to the upper forest boundary. Fir forests are the main representatives, amounting to about two-thirds

of the entire forest area. Beginning at altitidues of 2 300 to 2 500 m subalpine meadow vegetation gives way to vegetation of the alpine belt; this continues up to 2 800 to 2 900 m above sea level.

Fauna

The fauna of the western Caucasus is completely represented in the reserve by 59 species of mammals and 232 species of birds, of which more than 132 nest. Aurochs (*Carpa caucasica*), chamois (*Rupicarpa rupicarpa*), and wild boar (*Sus scrota*) are very numerous. Roe deer are found in the broadleaf forest belt. In 1940 the reserve began to breed aurochs in the Caucasus. There are currently 900 head in the Caucasus Reserve and neighboring territories.

Human Impact

Man's economic activity has had a minimum impact on natural conditions in the Caucasus Reserve. There was never any logging on its basic territory and a considerable area of the alpine meadows have never been grazed. There are no settlements on the reserve territory.

During its existence, the reserve has inventoried its flora and fauna and studied the biology and ecology of individual (especially rare) species. Since 1976, the reserve has begun the complex task of studying structure and dynamics of the basic ecosystems of the northwestern Caucasus. The territory is open for both expeditionary and stationary research.

Additional Information

References: Works of the Caucasus Reservation (vols. 1-2); Bannikov, A. G., Golgovskaya, K. Yu. Kotov, V. A. The Caucasus Reservation, Publishing House "Knowledge", 1967.

Staff: Full-time reserve staff totals 180.

Budget: The annual reserve budget is 290,000 rubles.

Address: U.S.S.R., 354067, Krasnodar Region, RSFSR, Sochi, Sukhumskoe Shosse, 7-A.

THE BEREZINA BIOSPHERE RESERVE

The Berezina Reserve is located in the White Russian Lake District on the territory of the Vitebsk and Minsk regions, 115 km from Minsk and 140 km from Vitebsk, in the square 54°30' to 55°00' northern latitude and 28°00' to 28°30' eastern longitude. The altitude of the reserve territory is 120 to 250 m above sea level. Its external boundaries encompass 76 201 ha, a protected zone of 33 000 ha.

In 1976 the reserve area was organized into two zones: A nuclear zone of absolute reserve character totalling 34 276 ha or 45 percent of the area and a buffer zone of 41 934 ha or 55 percent of the area.

Flora

In terms of botany and geography the reserve territory is within the subzone of broadleaf and spruce forests of the Russian plain. The forest area is 63 667 ha or 83.6 percent of the total. Thirty forest types are represented in the reserve. Pine, spruce, birch, and black alder forests prevail. There are also forests of oak, ash and linden. The non-forest areas are mainly swamps and meadows of three types. The flora of the reserve includes 698 species of flowers and higher spore-bearing plants which belong to 350 genera and 100 families (excluding mosses). Thirty-eight species of rare and declining plants are found on the reserve. Relics of the glacial period are the dwarf birch, northern *Linnaea borealis* and *Dentaria bulbifera* L.

Fauna

Recorded vertebrates total 293 species which include 52 species of mammals, 197 species of birds (152 nesting, 30 migratory, 6 overwintering, and 9 resident species). There are 5 species of reptiles, 8 of amphibians, and 33 species of fish. The basic and most valued animal species are beaver, elk, wild boar, roe deer, bear, woodgrouse, heathcock, and black and white stork.

Human Impact

The reserve was subject to human impact before its organization. At present the nuclear zone provides a completely protected regime. The ecosystems in the buffer zone are subject to economic use.

Potential for Scientific Studies

From 1961 to 1970 studies of abiotic conditions, the typology of forests and swamps, and the hydrologic regime were carried out in the reserve. During 1971 to 1975, studies were directed toward inventorying the natural objects of the reserve and developing measures for the protection and reproduction of the natural resources in the biogeocoenoses of the reserve.

The ecology and biology of single species and of basic forest ecosystems was emphasized. The reserve is located close to the Minsk-Vitebsk highway and has a road network for internal use.

Additional Information

References: Works of the Berezina Reservation: The Berezina Reservation. No. 1 (1970), No. 2 (1972); the Reservation on the Berezina, Publishing House "Harvest", Minsk, U.S.S.R. 1974.

Staff: There are presently 270 members of the full-time staff.

Budget: The annual budget of the reserve is 500,000 rubles.

Address: U.S.S.R., 211188, Byelorussian Soviet Socialist Republic, Post Office Domzheritsa, Lepel' District, Vitebsk Region.

THE OKA-TERRACE BIOSPHERE RESERVE

The Oka-Terrace Reserve is located in a valley on the left shore of the Oka River, 12 km to the east of Serpukhov, and 100 km south of Moscow. The reserve and the station are located in the square 54 to 55° northern latitude and 37 to 38° eastern longitude. The elevation of the reserve is 180 to 200 m above sea level with a reserve area of 4 945 ha.

The entire territory of the reserve is strictly protected. There are no buffer or other zones. In the northwestern part of the reserve there is an isolated area of 200 ha where a nursery was built for breeding aurochs.

Since 1976, the U.S.S.R. Academy of Sciences Experiment Station of the Institute of Agricultural Chemistry and Soil Science has carried out biosphere observations in collaboration with the reserve. There is a regular bus service with Pushchino on the Oka and Serpukhov.

Flora

The Oka-Terrace Reserve is located in the central part of the eastern European plain at the boundary of the broadleaf and mixed forest subzones. The reserve is covered by forests. The main forests are a rich variety of pine forest types. The vegetative cover of the reserve also includes: unique relict meadow-steppe phytocenoses with a large number of steppe and rare mountain species (e.g., *Aconicum authora, Conex obtusata, Dentaria tennifolia*); broadleaf forests of oak and linden; spruce forests and sphagnum swamps with elements of taiga flora (e.g., *Andromeda politolia, Oxycoccus quadripetalus,* and *Drosera rotundifolia*); and unusual steppe plants (e.g., *Stipa jeannis, Festuca sulcata, Phleum phleoides, Tulipa biebersteiniana, Cerasus fruticosa,* and *Veratum nigrum*) and other species (about 50) which are separated from their basic distributional area by 200 to 400 km.

Fauna

Fifty-three species of mammals and more than 130 species of birds are registered at the reserve. Among the basic species are representatives of broadleaf forests (e.g., *Clethrionomys glaredus*, *Apodemus flavicollis*, and *Discus viridis*); of the taiga zone (e.g., *Tetrao urogallus*, and *Tetrastis bonasia*); of open spaces (*Microtus arvalis*) and others (e.g., *Vulpes vulpes*, *Sorex araneus*, and *Alces alces*). River beaver, roe deer, and wild boar live on the reserve and in neighboring areas. Aurochs are bred under nursery conditions.

Additional Information

References: Works of the Oka-Terrace Reservation: Nos. 1-5 (1957, 1958, 1961, 1961, 1971); a pamphlet "The Oka-Terrace State Reservation," Moscow, 1974 (in Russian and English).

Staff: Full-time staff is presently 70.

Budget: The annual budget of the reserve is 140,000 rubles.

Addresses: The Oka-Terrace State Reservation: U.S.S.R., Moscow Region, Serpukhov District, Post Office Danki. U.S.S.R. Academy of Sciences Experiment Station, Institute of Agricultural Chemistry and of Soil Science: USSR, Moscow Region, Serpukhov District, Pushchino on the Oka.

THE CENTRAL CHERNOZEM BIOSPHERE RESERVE

The Central Chernozem Reserve is located within the central Russian highlands. The average altitude of the reserve is 250 m above sea level. The reserve area is 4 793 ha.

In consideration of the historically developed conditions, the reserve has a four-field hay-mowing regime. Each part of the steppe is mowed for three years and remains unmowed for one year. Constantly unmowed areas (having absolutely protected character) and areas for grazing have also been established in the reserve for comparative studies. In this way, the reserve includes all variations of steppe phytocenoses (mowed, unmowed, and grazed). In addition, there is a 1 km wide protection zone along the borders of the reserve. It functions as a buffer zone and reduces the influence of man's economic activities on the reserve. The total protected area is 8 663 ha. Economic activities within the protected areas are regulated.

Flora

The flora and vegetation of the Central Chernozem Reserve is typical for forest steppe in the European part of the U.S.S.R.

The reserve includes colorful broadleaf/grain meadow steppes, oak forests and associations with relict plants of the glacial period. Higher vascular plants total 863 species. These include 12 special species which are included in the Redbook of rare and endangered plants of the U.S.S.R.: *Adonis vernalis, Cotoneaster alaunicus. Crambe tataria, Fritillaria ruthenia, F. meleagris, Lilium martagon, Stipa pennata,* and others. Complex structures are a characteristic feature of the steppe associations of the reserve. The oak forests of the reserve are rare. Their extensive clearings are steppes. The most widespread oak forest types are: goutweed oak forest, mixed-herb oak forest, and bracken oak forest.

Fauna

The fauna of the reserve is typical of the Central forest steppe. There are 39 species of mammals, 150 species of birds, and several thousand species of insects. There is a high density of beasts of prey (birds and mammals) and of ungulates (elk, roe deer, and wild boar). The entomo-fauna of the reservation, in addition to widely spread European-Siberian groups, includes boreal, steppe, and Mediterranean species.

Research Possibilities

Long-term station-based studies of the forest steppe complex have been underway for many years. These concern the water and temperature regimes of the soil and dynamics of vegetation and animal populations on a seasonal basis and over many years. Detailed studies of the structural and functional organization of the dominant biocenoses of the forest steppe are carried out jointly by the Reserve and the U.S.S.R. Academy of Sciences Institute of Geography Experiment Station.

The Central Chernozem Reserve, since it is located in a region of intensive agriculture and developed industry, is able to successfully fulfill the role of a baseline area for the observation of changes in the natural environment.

Additional Information

References: Works of the Central Chernozem Reservation: Nos. I-II (1948-1971); Central Chernozem State Reservation named after Prof. V. V. Alekhin. Moscow, Publishing House "Forest Industry", 1968.

Staff: The permanent staff of the reserve totals 70.

Budget: The annual budget is about 100,000 rubles.

Address: U.S.S.R., 307028 Kursk, Post Office Zapovednoe, Central Chernozem Reservation.

SIKHOTE-ALIN' BIOSPHERE RESERVE

This reserve is in two parts: the main section is in the mountains of the central Sikhote-Alin' and a smaller section is along the Sea of Japan in the RSFSR Primorskie region. The reserve is located in the square 44°50' to 45°50' northern latitude and 135°45' to 136°45' eastern longitude. The elevations of the main watershed ridge of the Sikhote-Alin' on the reserve vary between 1 000 to 1 200 m above sea level. Some peaks reach 1 500 to 1 600 m. Elevations of the watershed frequently fall to 600 m. Low mountains are located along the Sea of Japan with elevations of 300 to 400 m. A small area is occupied by coastal lowlands. The reserve occupies 340 200 ha. The larger section is about 330 000 ha and the section along the Sea of Japan is 10 000 ha. The reserve has a buffer zone along its borders which is 1 km wide and has protection status.

At present a protection regime is observed on the entire reserve. Biogeocenoses which have undergone little modification are found on the territory of the reserve; these biogeocenoses undergo successful restoration without human intervention. The reserve is surrounded by a protective 1-km buffer zone. There are considerable forest areas next to the reserve subjected to constant intensive economic use. Two highways, with a total length of 70 km, go through the reserve.

Flora

The reserve is located within the limits of the east Asian coniferous-broadleaf and the South Okhotsk dark coniferous forest area--forests dominate. The east and west macroslopes of the Sikhote-Alin' are heterogeneous in vegetative composition. The dominant formation on the sea side part of the reserve consists of broadleaf-cedar forests where *Pinus koraiensis* dominates. The mainland side has dark coniferous fir-spruce forests with *Abies nephrolepis* and *Picea ajanensis*. In the main part of the reserve are unique cedar-fir-spruce forests with understory *Rhododendron fauriei* relict groups with *Echinopanax elatium*, and broadleaf-coniferous forests with *Primula jesoensis* in the ground cover. Slope exposure, altitude, temperature inversions, and other factors strongly influence the vegetation resulting in a shifting of belts. Generally the zones are clearly expressed, however, natural and purportedly natural valley broadleaf-cedar forests have the greatest floral variety. They contain more than 30 tree species, shrubs, and lianas and more than 80 grass species. The vegetation of the reserve includes representatives of the Manchuria, Okhotsk, eastern Siberia, and Mongolian-Daur types. The flora is saturated with relict and endemic forms and shows a wide compositional variety. The list of flora of the reserve presently includes 940 species of higher plants including 46 tree species and 68 shrub species.

Fauna

The reserve is rich in such southern animal species as goral, tiger, and Himalaya bear. Simultaneously, we find musk deer, wolf, glutton, brown bear, and many other palearctic species. On the whole, the animal world of the reserve is rich and diverse. We find 60 species of mammals, more than 300 species of birds, 12 species of amphibians and reptiles, and more than 30 species of fish.

Research Possibilities

During its existence, the reserve has conducted inventories of the flora and fauna, studied the biology and ecology of certain species of plants and animals (with rare and valuable species assigned highest priority), and collected information about natural ecosystem processes. Recently, work on problems posed by protection, reproduction, and rational utilization of the natural resources of the region has been intensified. The center is located in the district center of the settlement Ternei of the Primorskii region, on the shore of the sea. Vladivostok (660 km) and Khabarovsk (700 km) are the closest major administrative centers.

Additional Information

References: Works of the Sikhote-Alin' Reservation, Nos. 1-6; Collection: Flora and Vegetation of the Seaside Areas of the South of the Far East. (Works of the U.S.S.R. Academy of Sciences and the Sikhote-Alin' Reservation, new series, vol. 24, 127; 1975).

Staff: There are 90 permanent members on the staff of the reserve.

Budget: The annual budget of the reserve amounts to 260,000 rubles.

Address: U.S.S.R., 692150, Primorskii Region, Settlement Ternei, Sikhote-Alin' Reservation.

THE SARY-CHELEK BIOSPHERE RESERVE

This reserve is located between the spurs of the Chatkal mountain range facing towards the southeast. It is located in the southwestern part of the Kirghiz Soviet Socialist Republic to the northeast of the city Namagan, at 42° northern latitude and 71° eastern longitude. The elevation of the territory fluctuates from 1 200 to 4 300 m above sea level. The area covers 23 868 ha.

At present the reserve is divided into two basic zones: a zone of absolute protection and a buffer zone with forest cultivation and forest-related activities.

Flora

The flora of the reserve includes about 1,000 species of plants, among them 32 species of trees, 80 species of shrubs, and 880 species of herbs. The forest-shrub vegetation of the reserve is typical for the entire southern Kirghiz forest-fruit area. Representatives of the north and of the south are combined: relict walnut and firs (*Abies semenovii*), spruce (*Picea areuktiana*), and grapes. The elevational zones are clearly expressed in the vegetation distribution. Walnut is the dominant in the nut-fruit forests. Among the sparse growth of trees are found groups of apple and pear trees with an underbrush of *Prunus spinosa*, *abelia*, and *eaochordia* and *Juniperus taurica*. In the upper part of the belt the nut trees are replaced by spruce and spruce-fir trees. The apple tree forests occupy smaller areas in comparison with the nut forests. Thickets of pranges strike one's attention among the apple tree forests. The subalpine belt goes from a height of 2 100 to 2 200 to 2 500 to 3 000 m. In its lower part *Juniperus taurica* and fir-spruce forests are present. The trees and bushes become rare with increasing altitudes, gradually yielding to subalpine meadows with thick herbage.

Fauna

The reserve territory presently has 41 species of mammals, including 5 acclimatized species; 157 species of birds, 118 of which build nests; 5 species of reptiles; 2 species of amphibians; and 5 species of fish. The animal world, in both species numbers and numbers of individuals, is most richly represented in the forest belt. Wild boar and a large number of roe deer are the most characteristic large animals in this belt. In the fall the white-clawed bear is present in the nut-fruit forests. The animal world of the alpine and subalpine belts is distinct. In the reserve, there are mountain goats and mountain sheep as well as snow leopard. Ermine and stone marten can be found everywhere.

Human Impact

Since 1960 there has been no economic activity in the protection zone. Fire prevention and biotechnical measures are carried out in the buffer zone.

Research Possibilities

At present the reserve staff inventories flora and fauna and studies the biology and ecology of some species of mammals (beasts of prey and ungulates) and of birds. Special attention is given to the structure of the vegetative cover and the special features of the main species of fruit and commercially valuable trees and shrubs. This area can serve in an international research program as a baseline area for comparative indices on pollution. The territory is accessible for research.

Additional Information

References: A. I. Yanushevich and Yu. N. Chichikin: "The Sary-Chelek Reservation," in the collection "Reservations of the Soviet Union." Moscow. Publishing House "Mir", 1960; Works of the Reservation, Nos. 1-4.

Staff: There are 110 members on the permanent staff on the reserve.

Budget: The annual budget amounts to 90,000 rubles.

Address: U.S.S.R., 715705, Kirhiz SSR, Osh Area, Dzhangi-Dzhol' District, settlement Arkit, Sary-Chelek Reservation.

THE REPETEK BIOSPHERE RESERVE

The Repetek Reserve and the Sand-Desert Station are located in the Kara Kum desert, 70 km from the valley of the river Amu Darya, at 38° to 39° northern latitude and 63°00' eastern longitude. The elevation of the reserve is 180 to 220 m above sea level. The total area of the reserve is 34 600 ha. The Repetek Reserve is located in the central part of the eastern Kara Kum.

Zoning

The natural or nuclear zone can be identified in the territory of the Repetek Reserve and on areas close to it. The Reserve totals 15 000 ha. There is a desert portion which is completely intact. It includes the basic land forms of mobile and stabilized sands, basic vegetation formations of the Kara Kum, and the most characteristic representatives of the animal world. There are also experimental or buffer zones totalling 19 600 ha. Various experiments can be carried out in this area such as shrub cutting, cattle grazing, and stabilization of mobile sands.

Flora

The flora of the reserve is represented by 125 species of plants which belong to 24 families. Most characteristic are species of the families Chenopodiaceae (*Halolyxon persicum, H. ammodendron*), Doligomaceae (species of the genus *Calligonum*), Leguminosae, Cyperaceae, Gramineae, and others. Mosses are represented by one species (*Tortula desertorum*). The flora of higher fungi includes eight species, mainly species of the family Agaricaceae. The flora of the reserve is typically highly specialized along the line of *xerophily* and *psammophily*, and there are a large number of endemic species (37 percent).

The vegetation cover is represented by associations of four formations of desert vegetation: *Calligonum arboresceus, C. caput-medusae, Haloxylon persicum,* and *H. ammodendron.* Formations of *Calligonum* sp. can be found on mobile and weakly stabilized sands

and occupy 34 percent of reserve. The White Haloxylon formation includes various associations. The most characteristic of these are *Haloxylon persicum-Aristida pennata* which are developed on hilly sands slightly covered by grass and *H. persicum-Carex physodes* and *H. persicum-Carex physodes-Tortula desertorum*, which are characteristic for stabilized hilly sands. Associations of this formation occupy 44 percent of the reserve. Associations of the Black Haloxylon formation occupy a small area (5 percent) on valley-like lowlands. They are characterized by the greatest productivity of any of the sand desert associations.

Fauna

In the Repetek Reserve there are 10 species of reptiles and 21 species of mammals. Twenty-five species of birds build nests, and 12 are resident. In spring and fall 150 species of birds can be seen in the reserve. About 1,000 species of invertebrates live in the reservation. The biggest lizard in the Soviet Union (*Varanus griseus*) is found regularly as well as one of the biggest carabus (*Anthia mannerheimi*). The only poisonous snake (*Echis carinatus*) is common. On the whole, the reserve fauna is characterized by psammophily and by a significant number of endemics. Among the endemic vertebrates of the sand deserts of Tutan, *Eryx miliaris*, *Diplomesodon pulchellum*, *Paradipus ctenodactylus*, *Jaculus lichtensteini*, the thin-fingered gopher, and the Haloxylon jay are found on the reserve. About 70 percent of the invertebrates are endemics, a large part of which are found mainly in the sand deserts of the southern subzone. Seven species of rare and threatened animals, which can be found in the USSR Redbook, live in the reserve: *Varanus griseus*, *Gazella subgutturosa*, *Felus caracal*, *Vormela peregusna*, *Aregetus cailliaud*, *Agailla chyastus* and the desert sparrow (*Passer simplex*).

Human Impact

Human impact is absent in the natural zone. A moderate and, in places, significant grazing by sheep and cattle can be observed everywhere in the experimental zone. Natural methods for the restoration of natural conditions currently at different stages of anthropogenic change should be studied in this area in addition to methods of technical melioration and phytomelioration.

Research Possibilities

Long-term scientific studies of the Repetek Sand-Desert Station and Reserve include: the seasonal and long-term dynamics of some components of the sand-desert ecosystems; soil moisture regime; phenology, productivity and successive changes of the vegetation cover; composition and distribution of animals; and development of scientific foundations for a vegetation-oriented assimilation of desert territories, such as silviculture in the sand desert and the rational use of plant resources. At present, the main attention

is directed toward complex studies of the most typical ecosystems of the sand desert, of sand-hill sands with rare vegetation, of silt White Haloxylon communities on hilly sands, and of Black Haloxylon communities along valley-like lowlands. Most ecosystem studies were carried out under protected conditions. In international research, the Repetek Reserve occupies an important place, being a primary research site in the International Biological Program (IBP). The reserve and the Sand-Desert Station have railway and automobile connections with the large cities of Central Asia and are completely open to scientists. The regional center, the city Chardzhou, is 70 km from the reservation.

Additional Information

References: Miroshnik, V. P.: The Repetek Sand-Desert Reservation. In the book: "USSR Reservations", vol. 2, Moscow, 1951; Works of the Repetek Sand-Desert Station, vol. 3, Ashkhabad, 1955, USSR Academy of Sciences Publishing House; Works of the Repetek Sand-Desert Station, Ashkhabad, 1963, Turkmen SSR Academy of Sciences Publishing House. Studies and Development of the Eastern Kara Kum, Ashkhabad, Publishing House "Ylym", 1972; Biocenoses of the eastern Kara Kum, Ashkabad, Publishing House "Ylym", 1975; Rodin, L. E. (ed.): The Productivity of Desert Associations. In the collection: "Biosphere Resources", No. 1, Leningrad, USSR Academy of Sciences Publishing House, 1975.

Staff: There are 25 permanent members of the staff of the Repetek Sand-Desert Station and of the Turkmen SSR Academy of Sciences Reserve.

Budget: The total budget of the station and of the reserve amounts to 60,000 rubles.

Address: USSR, 746060, Turkmen SSR, Chardzhou Region, Station Repetek of the Central Asian Railroad, Repetek Reservation.

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