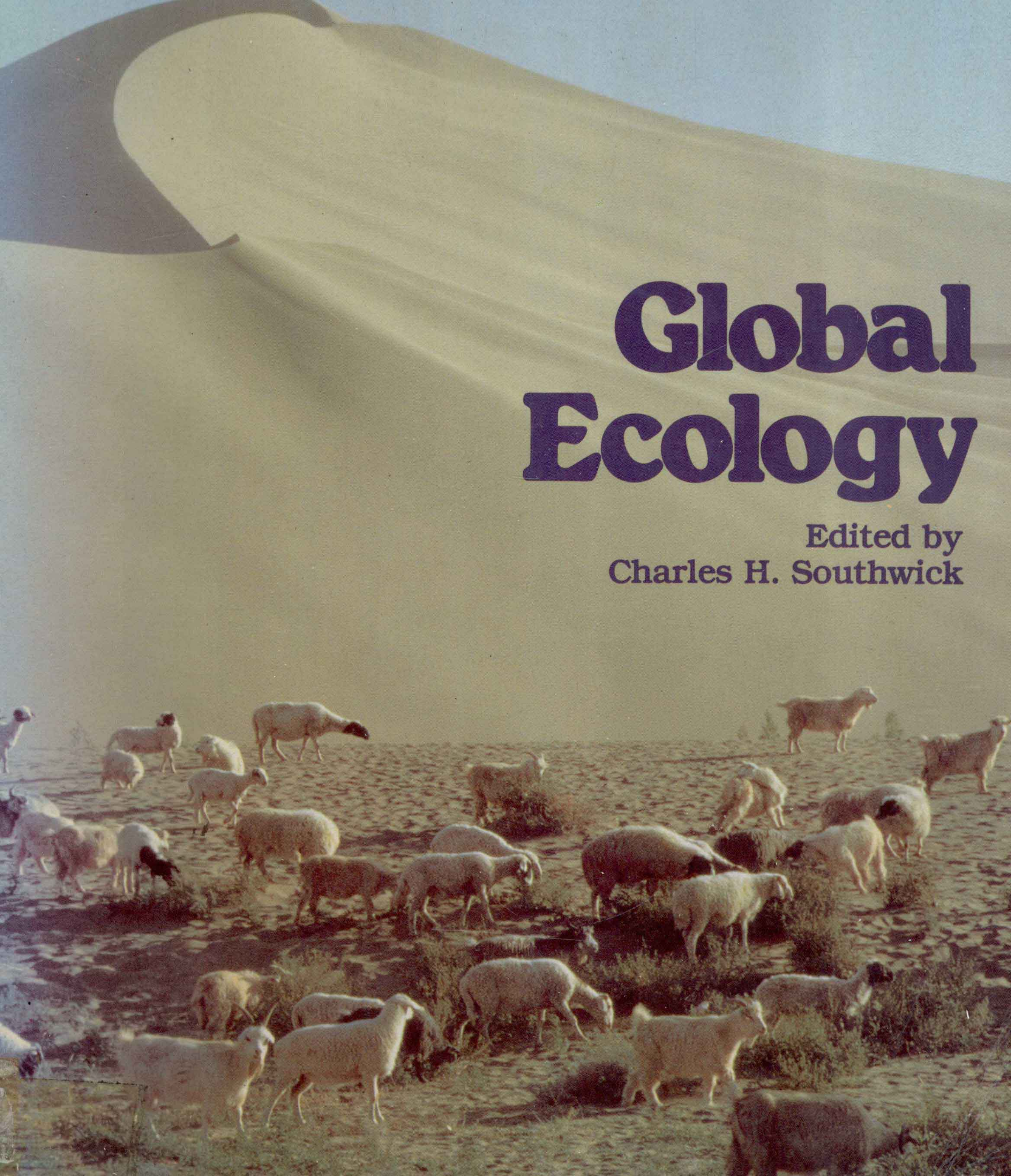

Global Ecology

Edited by
Charles H. Southwick

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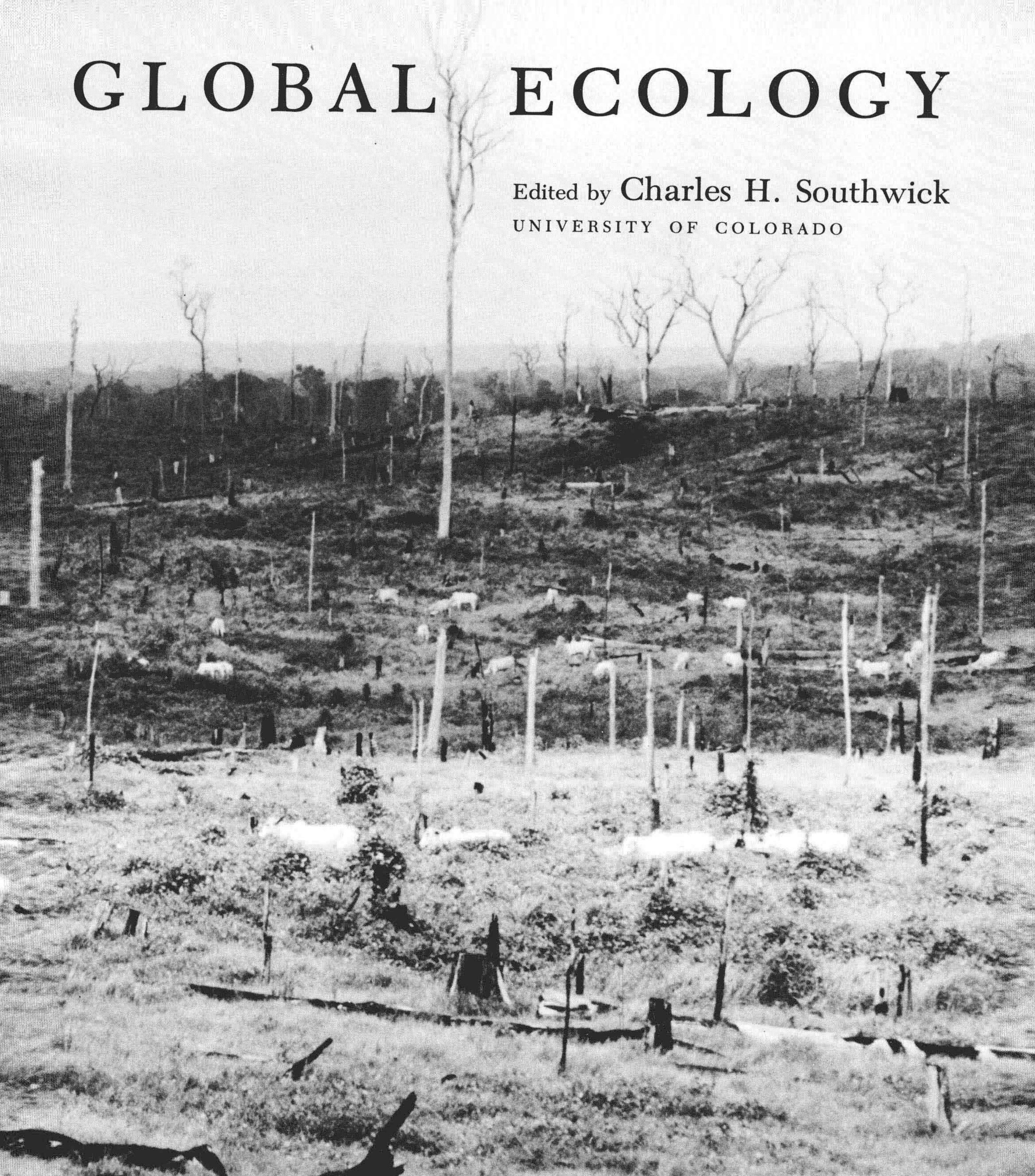
UNIVERSITY OF COLORADO



FRONTISPIECE

Tropical deforestation in Brazil. (Photograph by James P. Blair. Copyright © 1983 National Geographic Society. Reprinted with permission.)

THE COVER

The Sand Mountains of Gansu Province in western China. According to the Global 2000 report, the world's deserts will expand 20 percent by the year 2000. The United Nations has identified 2 billion hectares of land where the risk of desertification is high or very high. (Photograph by James L. Stanfield. Copyright © 1982 National Geographic Society. Reprinted with permission.)

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Preface

Although the concept of "One World" has been a popular idea among writers and politicians since the days of Wendell Wilkie in the 1930s, it did not become a visual reality until the space-age accomplishments of NASA in the 1960s. The astronauts on U.S. and Soviet space flights were impressed by the beauty and isolation of the earth. They saw its magnificent greens and blues and browns, surrounded by a swirling atmosphere of moisture-laden clouds. The impressions bordered on a religious experience for many of them. This was particularly true among the Apollo crews—as they receded from the life-giving earth to the lifeless moon, the contrasts were strong.

In more than twenty-five years of human activity in space, orbital flights have become routine, the use of space by science, industry, and human affairs has greatly expanded, and some impressions have changed as well. The astronauts of space shuttle *Challenger* reported in 1983 that they were shocked to see the amount of pollution surrounding the earth below them. Commander Paul Weitz stated, "Unfortunately, this world is becoming a grey planet . . . . Our environment apparently is going downhill . . . . We are fouling our own nest."

This realization is nothing new for most of us on earth. We have all experienced air and water pollution and the loss of a childhood field, forest, or pond to urban growth or suburban development. What is new is the fact that these changes are now visible from space, that they are affecting the entire planet.

These, and many scientific facts that come pouring at us from all directions, highlight the importance of global ecology. Global ecology is the study of ecological principles and problems on a worldwide basis. It has many components—some are simply the accumulation of local and regional events until they assume global importance, as may be true for acid rain, soil erosion, and coastal pollution, for example. Other events in global ecology are of such general planetary impact that they cannot be seen locally; new concepts and new approaches will be required to evaluate them. For example, chemical changes in the upper atmosphere or broad alterations in global heat balance can sometimes be measured locally, but their true significance involves more than the summation of local processes.

Thus, global ecology may be approached from many directions. One approach involves the physics and chemistry of the atmosphere and the interactions of the atmosphere with the oceans, land, and biota. Another is a more directly humanistic approach involving a look at our own populations and resources, our food supplies, our states of health and economics, and the conditions of our fellow travelers on planet Earth—a look at the condition of all the living organisms with which we share life support systems.

This collection of readings is based on the premise that these diverse approaches, from geophysics to world health, are all the valid domain of global ecology.

The book begins on the theme of the biosphere, its nature, extent, and some of its functional properties. This is followed by chapters with opposing views on the state of the world—the pessimistic projections of Global 2000 and the optimistic views of Julian Simon and Herman Kahn. These illustrate the range of opinions now available on global futures and human prospects.

The second section deals with ecological principles and trends—topics such as biogeochemical cycles, interactions of the atmosphere and hydrosphere, and measurable trends in global ecology. These chapters go beyond introductory textbooks, and they emphasize current areas of research. Chapter 8 provides one of the best real data assessments on worldwide environmental trends by which we can evaluate the pessimism and optimism expressed in preceding chapters.

The third section deals with human impacts on the biosphere—air and water pollution, land degradation, soil erosion, world food supplies, tropical deforestation, and desertification. These topics illustrate both ecologic and economic effects of human activities. Although most of the chapters in Sections II and III deal with the terrestrial environment, quite appropriately since this is where we live, Chapters 7 and 12 on marine ecology recognize that we do live on a watery planet, with more than 70% of the earth's surface covered by oceans, seas, and ice.

The fourth section focuses on human populations—demography, population trends, poverty, and world health, all representing a directly humanistic approach to global ecology. We sometimes forget that our own populations reflect global environmental conditions as well as alter them. This is especially true in the area of world health.

The book ends with a discussion of human prospects, biological diversity, environmental consequences of war, nuclear winter, and the roles of science and technology in guiding global futures.

I have chosen these readings because they represent the most important issues of our times—issues that deserve a broad audience among students in many fields; not only students in the biological sciences, but in the physical, behavioral, and social sciences as well, and certainly among students in the humanities, business, law, engineering, medicine, and public health. The issues of global ecology must receive the thoughtful and creative consideration of all of us in our collective search for solutions.

Acknowledgments

Many individuals and organizations have contributed to this collection of readings. I am indebted to my students and colleagues at the University of Colorado and Johns Hopkins University who have responded with keen interest and enthusiasm to discussions of global ecology, and I am grateful to all the authors and publishers of the articles in this book who have granted permission to use their materials.

I am also deeply indebted to many colleagues in India with whom I worked closely for more than 25 years and shared firsthand many aspects of global ecology.

My own research in ecology has been supported over a span of 35 years by various organizations, including the United States National Institutes of Health, the National Science Foundation, the U.S. Educational Foundation in India, and the National Geographic Society. During numerous trips through Asia, Africa, and Latin America I have enjoyed the encouragement, companionship, and insights of my wife, Heather, son, Steven, and daughter, Karen. They have shared with me the excitement and discouragements of viewing the world in ecological terms.

Practical assistance in typing these papers has been provided by Jeanie Cavanagh, Bryon Coe, Gretta Howell, Mary Marcotte, Barbara Miller, and Elizabeth Owen, all of the Department of Environmental, Population, and Organismic Biology of the University of Colorado. Finally, I am grateful to Andy Sinauer for stimulating discussions and editorial guidance on topics in global ecology.

CHARLES H. SOUTHWICK
Boulder, Colorado
January 1985

Contents

CHAPTER 1

The Biosphere

CHARLES H. SOUTHWICK

The biosphere is that part of the earth in which living organisms exist. It is a thin and discontinuous film over the surface of the earth, varying in thickness, and quite incomplete in surface coverage. It extends above the surface of the earth to altitudes that may reach nearly 10,000 meters or even greater heights when insects and microorganisms are carried aloft by updrafts and wind currents. The biosphere extends below the ground to the deepest roots of plants, to the chambers of many subterranean caverns, and in the oceans to the depths of thermal vents. In a few rare instances such as the Mariana Trench, these may conceivably provide a habitat for living organisms over 10,000 meters beneath the ocean's surface, although no organisms have yet been found at this depth. These are the extreme limits of the biosphere on earth and they emphasize the need to distinguish between various zones within the biosphere.

The broad definition mentioned above includes any place on earth or in the atmosphere where living organisms can be found. The extent of the total biosphere is quite different from those areas of earth where organisms may actively reproduce. With a few exceptions, the zone of primary biological production is much narrower. Its greatest extent on land is in a tall forest, such as a redwood grove or a tropical forest, where the zone of biospheric primary production (BPP)* may be 100 meters thick. At the other extreme on land, the zone of BPP in a rice field or a potato field is only 1 or 2 meters thick, and in a mown lawn, only a few centimeters thick.

In aquatic environments, the zone of BPP may be several hundred meters thick, for example, in a very clear ocean or lake where sufficient light can penetrate to support photosynthesis well below the surface. This depth of light penetration would require unusually clear water, but such conditions do occur in some marine and freshwater environments. Conversely, in a typical lake or ocean coastal zone, photosynthesis occurs in a layer of water that extends only a few meters below the surface, and in turbid waters, only a few centimeters.

The major exceptions to the preceding statements are deep-sea thermal vents, discovered only in recent years. These vents are cracks in the earth's crust on the bottom of the sea where hot gases and heated water emerge, often several hundred degrees centigrade in temperature (Matthews, 1981). Such vents have an incredible assemblage of marine life—uniquely adapted clams, marine worms, and crustacea capable of living in complete darkness, under very high pressures, and at extreme temperatures. In such habitats, photosynthesis does not occur; rather, primary production is accomplished by bacteria capable of synthesizing organic compounds from hydrogen sulfide. This undersea world is totally different from the biosphere as we know it on the surface of the earth. It operates with energy sources and metabolic pathways different from those of life on the surface, and it radically alters our concepts of where and how living organisms can exist. Figure 1 portrays in a diagrammatic fashion some of the vertical dimensions of the biosphere. It may help us visualize the great variation that occurs in both the depth and the thickness of the biosphere and in its lateral extent as well.

Despite the extreme environments in the deep-sea thermal vents where living organisms occur, there are many places on earth where the biosphere does not exist; or when living organisms are present, they are so transient or so sparsely distributed that they do not constitute a permanent biotic community. For practical purposes, the biosphere does not extend into the extremes of the polar regions, into vast areas of the driest

*BPP is used here in the same sense as GPP (gross primary production) is used in traditional ecology. That is, it refers to total organic synthesis in plants by photosynthesis and in microorganisms by chemosynthesis.

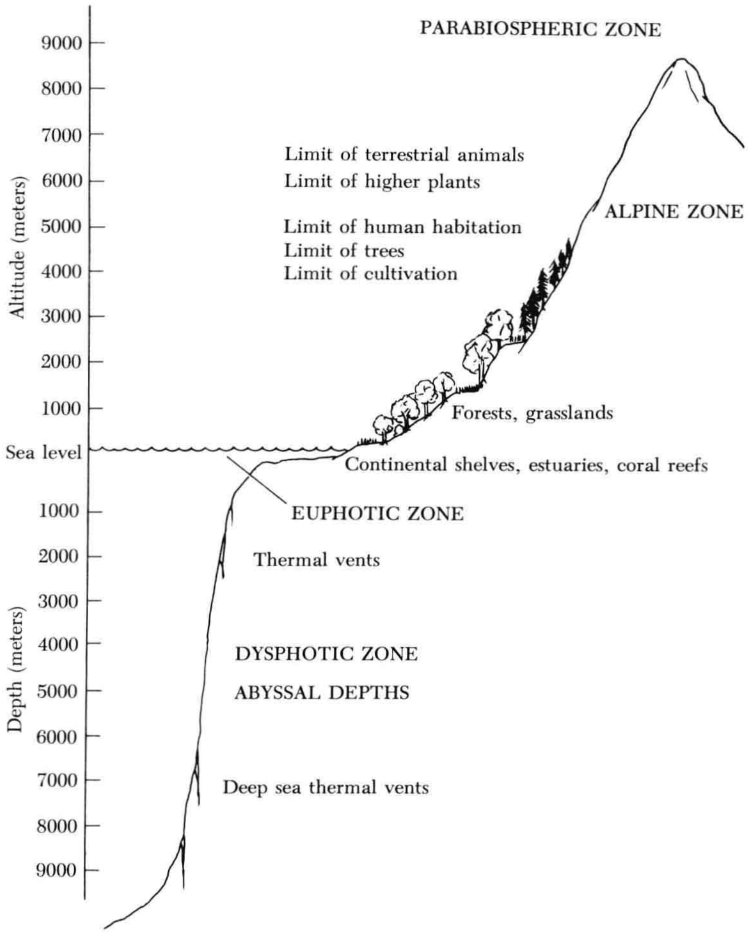

Figure 1 The vertical extent of the biosphere. The parabiospheric zone represents altitudes where only dormant forms of life, such as bacterial and fungal spores, exist. The euphotic zone in aquatic environments is the zone of active photosynthesis. (From Southwick, 1976; redrawn from Hutchinson, 1970.)

deserts, onto most of the highest mountain peaks that have an environment of permanent ice and snow, into some land and water areas most highly polluted with toxic wastes, and throughout some of the deepest ocean volume in places other than thermal vents and upwellings. Such areas may have transient life forms, but they do not contribute significantly to the total picture of biospheric production.

The relative thickness of the biosphere may be visualized by considering an analogy with more familiar structures. If the diameter of the earth is represented by the height of an eight-story building (approximately 100 feet or 30 meters tall) the total thickness of the biosphere would be represented by the thickness of a two-by-four board (approximately 4 centimeters) on top of the building. On the same scale, the zone of active biological production, excluding deep-sea vents, would be represented by the thickness of a piece of paper (approximately 0.3 mm), and even this thickness would represent the most favorable habitats, such as a clear coral sea or a tropical rain forest.

The point of this descriptive exercise is to emphasize that the biosphere is surprisingly limited. Meaningful terrestrial biosphere occupies less than one-quarter of the earth's surface, and it is continually subject to alteration and insult at the hands of human populations. Yet this biosphere is our total life-support system. It generates our oxygen, produces our food, reprocesses our wastes, and makes all life possible. As Christensen (1984) has stated, it is our "grand oasis in space."

Although it is an elementary exercise in biology to enumerate what a natural ecosystem does, it is worth listing some of these properties in relation to a nonliving system. What, for example, can a natural grassland accomplish that Astroturf or a parking lot cannot? Some of these accomplishments are listed in Table 1, which is perhaps too simple a reminder for an educated reader, but nonetheless is a set of facts collectively forgotten when we express no concern that we have been paving the biosphere with concrete and asphalt, chopping down its trees, washing away its soil, and polluting its air and waters.

We can also think of the biosphere as a mosaic of biochemical processes, an infinitely complex biochemical system. It captures, converts, processes, and stores solar energy through an incredible diversity of organisms. Despite the diversity of hundreds of thousands of species of green plants (perhaps 500,000) and microorganisms and the even greater diversity of animal species (perhaps 5 to 10 million, though only 2 million are known to science at the present; Ehrlich and Ehrlich, 1981), the fundamental structures of living organ-

Table 1. Simplified comparison of some system properties between a natural ecosystem and a man-made structure.

Natural ecosystem: pond, marsh, grassland, forest, etc.	Man-made system: house (non-solar) factory, parking lot, Astroturf, etc.
1. Captures, converts, and stores energy from the sun	1. Consumes energy from fossil or nuclear fuels
2. Produces oxygen and consumes carbon dioxide	2. Consumes oxygen and produces carbon dioxide
3. Produces carbohydrates and proteins; accomplishes organic synthesis	3. Cannot accomplish organic synthesis; produces only chemical degradation
4. Filters and detoxifies pollutants and waste products	4. Produces waste materials that must be treated elsewhere
5. Is capable of self-maintenance and renewal	5. Is not capable of self-maintenance and renewal
6. Maintains beauty if not excessively disturbed	6. Usually causes unsightly deterioration if not properly engineered and maintained
7. Creates rich soil	7. Destroys soil
8. Stores and purifies water	8. Often contributes to water pollution and loss
9. Provides wildlife habitat	9. Destroys wildlife habitat

From Rodale, 1972, and Southwick, 1976.

isms show remarkable similarities in basic organization. The patterned structures of DNA, RNA, proteins, lipids, and carbohydrates form a blueprint for all life. Modern biology is stretching our understanding and amazement of this living world on both molecular and global scales.

As this remarkable biosphere of which we are a part recycles biogeochemical products between itself and the physical components of the earth, it counters the physical process of entropy (the increase of disorder and disorganization) by constantly organizing, structuring, and rebuilding the biochemical basis of living organisms. Life itself can be thought of as antientropic in its phases of normal growth, whereas it is entropic in its processes of catabolism and decomposition. Without life the world would indeed proceed to disorder; with life, there can be productive reorganization.

The biosphere restructures its components not only in a physical and biological sense; it does so in a behavioral and social sense as well. Groups of ants, bees, fish, mice, deer, monkeys, and people all tend to establish behavioral and social systems. Social breakdowns occur, but from each process of social entropy, reorganization begins. In this elemental sense, a corporation after Chapter 11 bankruptcy or a nation after war follows the same basic process as a herd of deer or a covey of quail after the hunting season: a corporation or a society must reorganize, achieve a new structure, find new leaders, develop new routes of communication, establish new systems of political process. This is simply a broad expression of our recognition that there is order in the living world, order that can be disassembled or shattered, but order that can also be reassembled providing we do not entirely destroy an ecosystem's ability to do so.

The biosphere may also be thought of as a great moderator or buffer of environmental conditions on earth. One need only compare the summer ground temperatures of a bare earth field at midday to those in the shade of a deep forest at the same time to realize how much a plant community moderates temperature. In a similar way, the biosphere moderates humidity, wind, precipitation, oxygen and carbon dioxide balances, and many aspects of atmospheric chemistry. Forests provide enough moisture to the air through transpiration to help maintain the rainfall necessary for their own survival (McCormick, 1959). Aspen forests in Colorado have a significant buffering effect on acid precipitation (Kling and Grant, 1984), and most biotic communities have various capacities to detoxify certain pollutants.

All of these qualities relate to ecosystem homeostasis—the ability of biotic communities to maintain environmental conditions favorable for the perpetuation of life. When the biosphere is destroyed, physical conditions are more likely to swing to extremes—reasonable balances can no longer be maintained. These principles have many ramifications, often of direct importance to human survival. We know that natural drought cycles can be tragically exacerbated when the vegetative cover is destroyed by overgrazing or excessive land misuse. Temperature differentials become much greater when forests are destroyed. Flood conditions become more dangerous when watersheds are denuded. Storms may become more violent. The maintenance of equitable climates on earth is intimately associated with intact ecological systems (Schneider and Londer, 1984).

Traditional courses in biology are organized around some aspect of the biosphere—its complexity, its taxonomy, and its central functions. Some textbooks of biology are entitled *Biosphere* (Jessop, 1970; Wallace et al., 1984). Within the study of the biosphere, the focus may be the cell, the organism, the population, or the ecosystem. At each of these levels, the interplay of diversity and unity is an impressive theme. At the most comprehensive biological level of all, the biosphere itself, this theme is also the logical one to emphasize. But perhaps it is even more important for us to realize what we are doing to the biosphere. How are we affecting the earth's ability to function as a life-support system? That question is a critical one, not only for ourselves, but for millions of other organisms. It is easy to see local effects at many points, but how important are these in a cumulative sense? Are numerous arenas of local pollution and countless scars of erosion, deforestation, and desertification altering the function of the global system? Or are they negligible? When we examine data on global increases in CO_2, accumulation of airborne lead in the Greenland icecap, DDT in the penguins of Antarctica, and expansions of the deserts of Africa, we have evidence of global influences.

Although the earth is a vast assemblage of infinitely complex and varied environments, we must also think of its total health. Global concepts are more essential than ever before—they can provide guidelines for local action and clues for what we might expect from local or regional developments when seen in broader perspective.

Hence this book. It cannot possibly cover the entire subject of global ecology, but it does provide a collection of outstanding articles, written by experts in their fields and covering an array of ecological topics from global atmospheric chemistry to world health. Collectively, these articles address various aspects of how we are impacting the biosphere, what some of the consequences might be, and what we might be able to do about it if we are sufficiently informed and concerned.

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SECTION I

DIVERGENT VIEWS ON THE STATE OF THE WORLD

CHAPTER 2

The Global 2000 Report

PREPARED BY THE COUNCIL ON ENVIRONMENTAL QUALITY AND THE DEPARTMENT OF STATE

Letter of Transmittal

The President

Sir: In your Environmental Message to the Congress of May 23, 1977, you directed the Council on Environmental Quality and the Department of State, working with other federal agencies, to study the "probable changes in the world's population, natural resources, and environment through the end of the century." This endeavor was to serve as "the foundation of our longer-term planning."

The effort we then undertook to project present world trends and to establish a foundation for planning is now complete, and we are pleased to present our report to you. What emerges are not predictions but rather projections developed by U.S. Government agencies of what will happen to population, resources, and environment if present policies continue.

A report prepared by the Council on Environmental Quality and the Department of State for the President of the United States. Volume I, Summary: Entering the Twenty-First Century (1982). Gerald O. Barney, Study Director. U.S. Government Printing Office, Washington, DC 20402.

Our conclusions, summarized in the pages that follow, are disturbing. They indicate the potential for global problems of alarming proportions by the year 2000. Environmental, resource, and population stresses are intensifying and will increasingly determine the quality of human life on our planet. These stresses are already severe enough to deny many millions of people basic needs for food, shelter, health, and jobs, or any hope for betterment. At the same time, the earth's carrying capacity—the ability of biological systems to provide resources for human needs—is eroding. The trends reflected in the Global 2000 Study suggest strongly a progressive degradation and improverishment of the earth's natural resource base.

If these trends are to be altered and the problems diminished, vigorous, determined new initiatives will be required worldwide to meet human needs while protecting and restoring the earth's capacity to support life. Basic natural resources—farmlands, fisheries, forests, minerals, energy, air, and water—must be conserved and better managed. Changes in public policy are needed around the world before problems worsen and options for effective action are reduced.

A number of responses to global resource, environment, and population problems—responses only touched on in the Study—are underway. Heightened international concern is reflected in the ''Megaconferences'' convened by the United Nations during the last decade: Human Environment (1972), Population (1974), Food (1974), Human Settlements (1976), Water (1977), Desertification (1977), Science and Technology for Development (1979), and New and Renewable Sources of Energy, scheduled for August 1981 in Nairobi. The United States has contributed actively to these conferences, proposing and supporting remedial actions of which many are now being taken. We are also working with other nations bilaterally, building concern for population growth, natural resources, and environment into our foreign aid programs and cooperating with our immediate neighbors on common problems ranging from cleanup of air and water pollution to preservation of soils and development of new crops. Many nations around the world are adopting new approaches—replanting deforested areas, conserving energy, making family planning measures widely available, using natural predators and selective pesticides to protect crops instead of broadscale destructive application of chemicals.

Nonetheless, given the urgency, scope, and complexity of the challenges before us, the efforts now underway around the world fall far short of what is needed. An era of unprecedented global cooperation and commitment is essential.

The necessary changes go beyond the capability of any single nation. But our nation can itself take important and exemplary steps. Because of our preeminent position as a producer and consumer of food and energy, our ef-