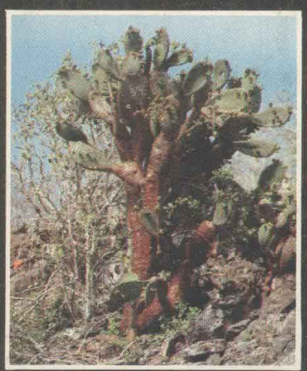
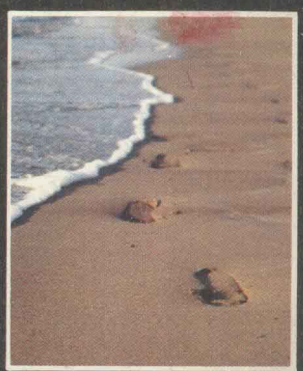
SECOND EDITION

# The challenge of ecology

Clair L. Kucera





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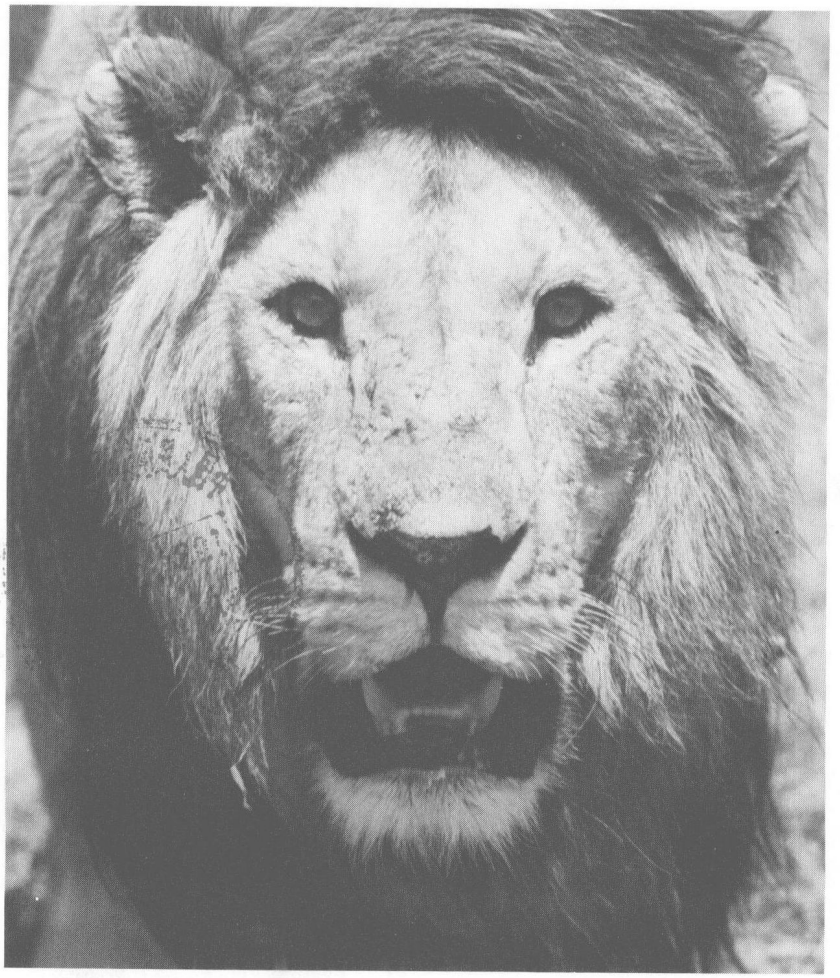


# Prologue

> We travel together, passengers on a little spaceship, dependent on its vulnerable reserves of air and soil, security and peace, preserved from annihilation only by the care, the work and love we give our fragile craft.
>
> ADLAI STEVENSON, 1965

These words have a prophetic ring as we view an ever-changing and depreciating environment. People are the dominant species on earth. Through our power and technology, we are able to manipulate, change, even destroy our habitat. Today we know that large-scale modifications are in process, and they continue at an ever-faster pace. The oceans, despite their vastness, are virtually nowhere free of pollutants. These include oil spills, toxic chemicals, and radioactive wastes. Some of our deepest lakes show steady deterioration in water quality. Their self-cleansing biological processes can no longer cope with the constant intrusions of industrial wastes. Our rivers, literally, are open sewers. The air is no longer clean. Smog hands in a pall-like shroud over major cities, often dimming the sun for days at a time. Whole landscapes are being destroyed, stripped of vegetation and viable topsoil. Pesticides, among other chemicals, have appeared and continue to appear in our food and water supplies. The list of environmental injuries is long, persistent, and commonplace. The human-made revolution going on in the environment today is a sober reminder of the widening gap between expanding technology and shrinking ecological balance. As these impacts continue, it is inevitable that change and instability will also increase. The quality of our lives, if not life itself, is being challenged.

Our earth is indeed a spaceship. It has a limited life-support system for sustaining a human population. Its carrying capacity is finite. Some say we have already exceeded it, if certain goals concerning living standards are to be maintained. Undoubtedly if such goals for all peoples are to match those currently enjoyed by Western industrial countries, the carrying capacity of the earth in terms of available resources is already oversubscribed. In the United States alone, with a little more than 6% of the world's population, we use an average of 30% to 35% of the earth's resources and energy produced each year. The material comforts we have come to accept as daily necessities are not without their price in terms of growing pollution and diminishing resources. Stated in another way, such demands are reflected in the statistic indicating that in the last 30 years more materials were used in this country than in the rest of the world combined.

Throughout human history, we seemingly have taken our natural resources and wildlife heritage for granted, if our treatment and use of them are any guide. Picture the deci-

mation of the bison herds in North America, the actual extinction of the passenger pigeon, or the creation of the Dust Bowl in the Great Plains during the 1930s—all this in less than a century. The exploits of the ancient world are no less impressive. The denudation of Mediterranean lands, the expanding deserts of Africa, and the disappearance of forests everywhere are convincing proof of civilization's influence.

Unfortunately the philosophy of exploitation so characteristic of us and our traditional view of nature persists even today, as resources continue to give way to development. In the United States 5 acres of open space disappear every 1½ minutes under the impact. Around the world the land and waters are undergoing severe pressure to feed and serve more people. Starvation and malnutrition take their toll at the rate of one death every 8 seconds! Yet a conservative estimate places the net growth of the earth's population at 70 million people every year, a population equivalent to one-third that of the United States! With each additional increment in world growth, the quality of human life can only deteriorate. Projections are that in less than 30 years there will be twice as many people for whom food and living space will be needed. The oceans cover about 70% of the earth. They are an important source of protein in the harvest of commercial fisheries. Ironically, however, less than one tenth of the ocean supports food chains that can produce usable food for human consumption. The sea is not as large as it would seem to those who would rely on it to feed an unrestricted growth of human populations.

An irrefutable fact about our environment, then, is its limited resources. There is just so much usable water. Oxygen, minerals, and space for growth of whatever form, too, are measurable only in finite quantities. The environment is also fragile, vulnerable to the effects of industrial and technological development, and always in a state of delicate balance. Our planet in effect is one vast working system of interlocking functions and processes. We might ask how much longer, short of complete breakdown, the environment can sustain the pressures of use and the impacts of disruption that arise from expanding economies and the needs of growing populations. The day is here when we should recognize these ecological restraints on our management plans.

The universality and oneness of our plight in a finite and constantly degrading environment would seem an effective impetus for concerted action in solving mutual problems. A litany of facts, figures, and statements about a dismal future, however, is not enough. Alone, such a jargon may do a disservice to constructive action, for it may instil a fatalistic attitude toward the total environmental picture. There are other considerations. If we are to save our environment, arrest its further decline, and mend the damage already done, awareness, concern, and new attitudes toward nature are needed. We must bring about a reordering of priorities in our traditional approach to natural wealth. Our philosophy of continuing growth and corporate bigness as synonyms for progress should be replaced by a planetary concern for the quality of human living. What, then, should be done to ensure a native environment that provides not only the basic necessities for survival but also those intangibles such as biotic diversity, natural beauty, open spaces, and quiet surroundings that enrich human life?

Constructive measures applied through forward-looking and far-reaching educational programs are the main basis of hope in meeting the ecological challenge. These programs

would combine innovations and interdisciplinary approaches. All areas of scholarship and learned endeavor in science, the humanities, and the social sciences must be involved. So often ecology and the environmental crisis are equated in cognate fashion, but erroneously so. The environmental crisis deals with people. It is caused by people, and a reciprocity in kind is implied when helpful dialogue and pragmatic solutions are sought. Thus implementation of corrective proposals will require the support of all segments of society. Only through instilled appreciation and an understanding of human-related causes and their interaction with ecological processes can meaningful progress be made.

For example, would a broader understanding of species diversity as a functional concept in maintaining ecosystem stability help change attitudes toward predators? Would a more broadly based knowledge of environmental resistance as a mechanism in control of a native species, thereby ensuring its future, assist in changing attitudes about our own population growth? Such examples are numerous. Much basic information is already available concerning environmental relationships across a wide front of ecological observations. It is true that the studying, the measuring and sampling, and the empirical effort should go on in the testing of hypotheses and the advancement of knowledge. But the extrapolation and extension of this knowledge into new domains are also needed. Neither is it a one-way street. The interactions that develop should provide a catalyst for synergistic accomplishment.

What are the real and significant confrontations between ecological processes and the environmental crisis? The purpose of this text is to show such relationships wherever they occur. It is hoped that this presentation will provide for beginning students, our learned colleagues in other disciplines, and nonprofessionals generally a better understanding of the interphase between such ecological values as diversity and stability and man's impositions that have led to the present situations. New dialogues and exchange of viewpoints are keys to awareness, to concern, and, hopefully, to a reorientation in public attitudes toward the use of resources. Without a change in our thinking, there can be no real abatement of the environmental problem. Our efforts become a series of post-factum skirmishes between groups sympathetic to environmental quality and vested interests as each emergency arises.

As our general condition worsens, a situation may arise from which there is no redress. An overview policy at high government levels, given impetus by an informed citizenry, might provide the legislation that could result not only in an early cure of the damage already effected but more importantly in the prevention of future alterations.

In the first edition I envisioned hope for the future regarding the conservation of resources and the preservation of our surroundings. The Environmental Protection Agency (EPA) was formed in 1970 by federal statute. The Council on Environmental Quality was also created, with its broadly based role as advisor and coordinator at the national level. In the international sphere, the United Nations sponsored a conference held in Paris in 1971 entitled "Man in the Biosphere." Here, problems were addressed to population and resources in the global perspective. A year later the United Nations Conference on the Human Environment was held in Stockholm, again dealing with global issues. In 1973 an international meeting on endangered species of animals and plants was con-

vened in Washington, D.C. Since the publication of the first edition, limited gains have been made on various fronts. Our environment in the overview, however, still continues to deteriorate from long-standing threats as well as from ones not even known 5 years ago.

Our problems are exacerbated by the energy crisis, of which we suddenly became aware in 1973 with the oil embargo, and by the persistent worldwide food shortage, particularly with regard to protein needs, in developing countries with explosive population growth. The United Nations World Population Conference held in Bucharest in 1974 was a disappointment. Clearly there is no universal agreement concerning the urgency of controlling population on a worldwide scale. On the contrary, some developing countries with high birthrates view with suspicion the affluent nations for advocating birth control measures in their countries. Yet if the human species is to prevail on this planet within a civilized framework and a social order, we must arrive at some accommodation with global resources. This can only be achieved by a reduction in population growth and by conservation of resources, leading ultimately to an equilibrium condition between man and nature. The choice is ours to make. The time is late, but not too late. If we choose not to implement our words with positive action, we invite armed conflict and an uncertain future for all. If, however, we start now to cope realistically with expanding populations and shrinking resources, we can and will, like Prometheus, yet prevail.

Many persons contributed to the preparation of this book. I wish to express a deep appreciation to all for their assistance. Special thanks are extended to Rosemary Crane and Cindi Williams who typed the manuscript and to Ruth Dalke. Liz Hollis made additional drawings. Jim Alexander gave many hours in reference assistance. In addition, numerous correspondents kindly provided photographs or granted permission for the use of diagrams and tabular data from various publications. Several agencies should be noted, especially the Missouri Conservation Commission, the United States Forest Service, the Soil Conservation Service, the United States Geological Survey, the California Water Resources Board, the Alaska Cooperative Wildlife Research Unit, the State of Alaska Department of Environmental Conservation, the Serengeti Research Institute, and the Environmental Protection Agency. My appreciation is extended to Drs. Stephen Chaplin and John Faaborg for their preparation of Chapter 10 and to Dr. Arthur Witt for his assistance with Chapter 2, dealing with freshwater systems. Last but not least I wish to thank my graduate students and several faculty members for evaluation and critique of certain parts of the manuscript.

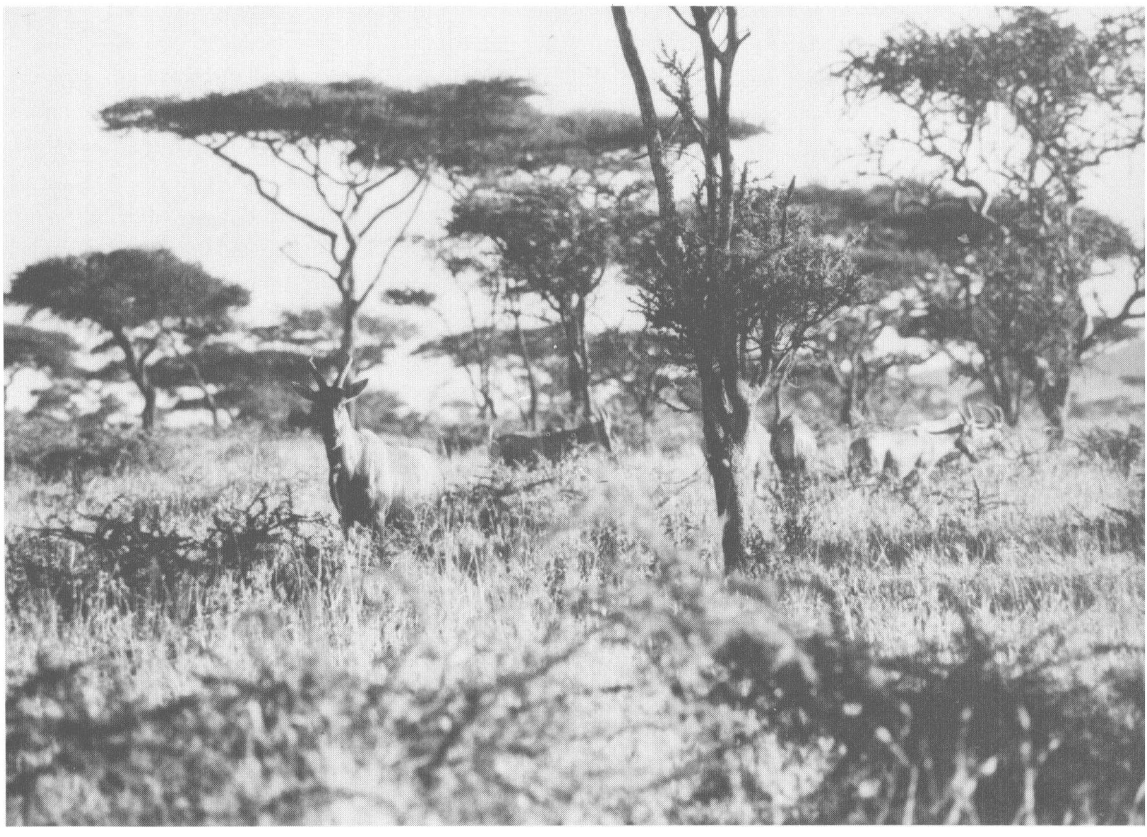
**Clair L. Kucera**

# Contents

# PART ONE

## Introduction

# 1 A common ecology



## MAN IN THE ENVIRONMENT

People have always had a vital interest in their environment. Their mode of living depended on it. The tools they developed, the types of dwellings they built and occupied, the foods they gathered, and the forage they used for domesticated animals have of necessity reflected an awareness of the resources available to them. Local environments were important to their survival, and they adjusted accordingly. As their skills improved, the number of artifacts increased to more effectively cope with their environment. Until approximately 10,000 years ago, they were fruit gatherers and later hunters. Then followed in successive order their roles as nomadic pastoralists and agriculturists, or tillers of the soil. The first food crops were probably grown in the Middle East, and it is here that archeological evidence suggests the construction of the first villages. Such early attempts at urbanization had their roots in these primitive human communities.

With improved methods of agriculture and more effective storage, both the amount of available food and the reliability of its supply increased. Transportation systems became more efficient, and food could be shipped from distant sources. Populations grew gradually and began to concentrate in cities. Crafts of increasing number and complexity emerged as more time became available for specialized tasks in the making of goods and the delivery of services. No longer was the day-to-day involvement with gathering food a person's sole existence. This succession of events in human activities resulted in national industrialization, becoming most advanced in western Europe and the United States.

Accompanying these changes in human life-style was a growing impact on the environment, measurable in terms of greater attrition of natural resources such as soil fertility, increasing pollution of the water and air, and a diminishing number of wildlife species.

Underlying these effects of human endeavor, today there is one basic, all-pervading stimulus—that of increasing densities of human populations. This, coupled with a greater affluence and the desire for even more material comforts, provides an incontestable basis for ever-mounting pressures being exerted on the environment. Unless these pressures on space and food resources can be curbed and brought into line with the earth's carrying capacity, the status of our habitat will continue to depreciate. *A finite system devoid of checks is also one without balance.*

## WHAT IS ECOLOGY?

Ecology is a relatively new science. It was accepted as an organized discipline with a body of accumulated knowledge at the beginning of the century. Its foundations, however, were laid much earlier, with the classification of plant and animal life, the development of the science of biogeography, and the acceptance of Darwin's theory of evolution. What conditions might warrant such recognition for this or any other field of scientific interest? Concepts are based on stores of relevant information derived from patient and sustained observation. This process of gathering information and organizing it rationally is never ending. The synthesis of generalizations fashioned from details, facts, and particulars is an integral part of the scientific method. In turn, the inductive process serves

as the means by which new ideas are generated and tested and old ideas are reevaluated. As we advance the scope and depth of our knowledge and relate it to information provided by other interests and professions, the whole provides a more comprehensive understanding of natural phenomena. The very necessary human preoccupation with environmental relationships for thousands of years has provided us in recent times with a unified approach to scientific inquiry.

Ecology is the study of interrelationships among organisms and their surrounding habitat. Specifically we might ask how plants and animals interact with one another. What are the effects and limitations of the physical environment in relation to such processes as photosynthesis, nitrification, and organic decay? Are there different degrees of biotic tolerance to such factors as temperature, salinity, and moisture? To what extent is the habitat modified by the interaction of these factors? What are the biotic changes associated with successional maturity?

Through this complex of relationships runs a common thread of interdependency. A factor initiated at one point in the environment may produce a chain reaction whose final effect is felt far from the source. There is abundant evidence of this cooperative relation between biological and physical processes. We have seen it in reports of DDT in Antarctic penguins, mercury in swordfish, or radioactive strontium in our milk supply. Still other examples might be mentioned such as the polychlorinated biphenyls (PCBs) whose subtle presence in food chains has only recently come under close scrutiny as a human health hazard. It is literally true that no species, including man, lives in complete isolation from any other species. Neither can any species live apart from its physical environment, although migration, hibernation, and dormancy are adaptive mechanisms that help organisms to avoid extreme or otherwise intolerable stresses that occur on a periodic basis. The biosphere is an "ecological web," linking all life and its external medium of air, water, and soil in a common whole (Fig. 1-1). These binding interactions do not

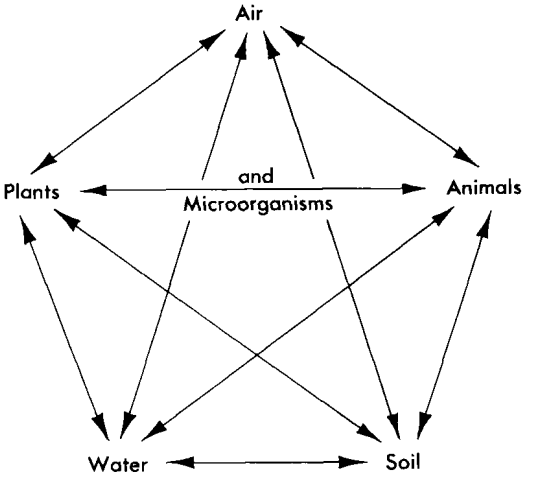



**Fig. 1-1.** Schematic diagram of interrelationships of the biological and physical components of the ecosystem.

always work to the advantage of the organisms in a given system. The examples just cited show that toxic or harmful substances as well as life's essentials often move through the biosphere with equal facility.

## COMMUNITY ORGANIZATION

The worldwide complex of life presents a heterogeneous but orderly and generally continuous pattern of plant and animal assemblages. These assemblages are biotic communities, each characterized by a mutualism among its members and certain distinctive features that permit its identification and differentiation from other communities. The Alaskan tundra is a type of community. It suggests to the initiated an array of plant species and just as readily a list of animal associates. To know one is to have some measure of understanding of the other. So, too, with a Colorado grassland or a rain forest in Costa Rica.

Species organization is thus a key feature of most communities, obviating randomness of relationship, particularly in those systems that are generally mature or in the later stages of development. However, species composition often approaches randomized assortments in communities that are pioneering new areas such as a recently created volcanic deposit or a river sandbar. Such assortments result from the haphazardness of plant dispersal, particularly that which results from the scattering effect of wind-borne spores or seeds. In time successive invasions and species replacements fill bare areas, and competition for resources becomes a more exacting determinant in an emerging species structure.

Biotic communities differ in the number and variety of plants and animals that occur in a given habitat. Some communities are relatively diverse and contain numerous species, whereas others have but a few. Diversity indices have been devised to provide a mathematical basis for making comparisons between communities. Some examples will be discussed in Chapter 4. Communities vary in the way in which they are structured. The spatial arrangement of species and their densities, size and age distributions, and life form are all aspects of community structure. The characteristic size of a grazing herd of ungulates or a school of fishes or the spacing of plants in the desert are expressions of community organization.

## LIFE FORM AND ADAPTATION

Life form is a striking property of community structure. We see differences immediately between the low tundra vegetation of the Far North and the tall grass prairies of the Midwest, between the deciduous forests of New England and the semitropical evergreen aspect of southern Florida. The following simple classification for plants has been devised by the Danish botanist Raunkaier:

| | | |
|---|---|---|
| Phanerophytes | (P) | Trees, shrubs, and vines; buds, more than 0.5 meter above ground, aerially exposed throughout year |
| Chamaephytes | (Ch) | Perennial herbs or low shrubs with buds less than 0.5 meter above ground |
| Hemicryptophytes | (H) | Herbs dying back to ground level; renewal buds at ground level developing from a rosette of basal leaves |