A landscape photograph showing a calm body of water, likely a lake or a wide river, reflecting a cloudy sky. The water is dark, and the reflection is clear. In the foreground, a wooden fence post stands vertically, with two horizontal wires or rails extending from it across the frame. The background consists of rolling hills or mountains under a sky with scattered clouds. The overall tone is somewhat somber due to the dark colors and the overcast sky.

Introduction to Environmental Science

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Preface

Much of the excitement that characterized concern about the environment in the late 1960s had waned by the middle of the 1970s, and in its place the problem-oriented, interdisciplinary field of study known as environmental science had begun to evolve. This relatively new field, now an established academic program, is marked neither by emotionalism nor by fatalism; rather, it represents an attempt to assess the environmental problems of our technological society objectively and rationally. In this context, problems and their possible solutions are studied carefully, and decisions more often involve compromise and cooperation than finger-pointing and reproof.

As the title suggests, *Introduction to Environmental Science* is meant to introduce students to this field of study. The book is intended for students who do not plan to major in physical or biological sciences, and we presume no prior experience with science. We examine environmental problems in the framework of well-founded physical and biological principles. However, the discussion of each of these principles is developed only to the extent that it directly

contributes to the students' understanding of the problem at hand. The product, we hope, is an uncluttered, systematic exposition that will appeal to reason rather than to emotion.

One of our fundamental objectives is to show students how environmental problems and controversies affect them. We try to accomplish this by briefly reviewing the normal functioning of the relevant part of the environment; examining the problem in its historical perspective; identifying the attitudes and activities that contribute to it; and pinpointing (when possible) its political, legal, economic, and social aspects.

In coming to recognize the personal sacrifices and trade-offs necessary to improve environmental quality or to contribute to resource conservation, readers will gain an appreciation of the difficulties of resolving environmental problems on a local, national, or worldwide scale. At the same time, they will learn to determine what each of them can do to help solve such problems.

We do not presume to tell students what course of action they should adopt. Instead, we present a num-

ber of alternatives—including inaction—and we discuss their consequences. It is our hope that the holistic view of problems presented here will help readers to make informed, realistic choices. They should come to understand that different situations dictate different responses, and that blind adherence to the extreme of environmental purity or that of unbridled exploitation may result in a situation to which there can be only one outcome: severe hardship.

Organization

Beyond the introductory chapter, the book is divided into three major parts: Part I, Concepts of Ecology (Chapters 2–5); Part II, Environmental Quality and Management (Chapters 6–15); and Part III, Fundamental Problems: Population, Food, and Energy (Chapters 16–20).

Part I surveys the fundamental principles that govern the functioning of the environment. What is the natural flow of energy and materials through the environment? How do organisms and ecosystems respond to change? Why and how do populations grow? Readers will gain an understanding of these and other points that they can apply to their comprehension of more specific issues later in the book.

Part II explores dominant issues of environmental quality and management: water and air pollution; exploitation of the earth's rock, mineral, and fuel resources; waste disposal; endangered species; and conflicts in land use.

Part III focuses on problems at the core of most environmental issues: growing human population and shortages in food and energy resources.

This book is designed for one-semester courses on environmental science. Recognizing that topic coverage in such courses varies from college to college, we have included a wide variety of topics, organizing the coverage in such a fashion that chapters or parts of chapters—especially in Part II—can be omitted without loss of continuity.

Features

We have included several features in our book that make it an effective teaching and learning text.

Pedagogical Aids

Each section begins with a statement of objectives, and each chapter ends with conclusions, summary statements, review questions, suggestions for group and individual projects, and an annotated bibliography. Both metric and British units of measure appear throughout the text and in many tables and illustrations. There are appendixes of scientific conversion factors, geologic time, and powers of ten notation.

Boxes

Where a deeper scientific explanation of certain topics—for example, net energy analysis and the nature of nuclear power plants—seems desirable, we have included complementary information set off from the text in boxes. Where specific examples will illuminate the social, political, economic, or personal aspects of such environmental conflicts as the channelization of the Kissimmee River and the poisoning of the Love Canal, brief case studies are included in box form.

Illustrations

To bring more realism to the book we have included an unusually large number of high-quality photographs and line drawings. More than 400 illustrations—photographs, drawings, maps, and graphs—illustrate and clarify important points.

Glossary

All important terms are italicized and defined at first use in the text. They appear again in the glossary, which, with more than 350 entries, functions as a minidictionary of environmental topics and terms.

Supplementary Materials

The text is accompanied by an Instructor's Manual that contains learning objectives for each chapter, test questions (each with a parenthetical reference to the page in the book on which it is answered), topics of current concern for discussion or research, and a list of recommended slides and films that instructors might wish to obtain for classroom use.

Acknowledgments

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One of the most difficult challenges of writing an introductory science text for nonscience majors is communicating sophisticated concepts in terms that are readily understood. Suzanne Lipsett, our manuscript editor, and John Hendry, the editor of boxed material, met this challenge with skill and precision.

September 1979

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Satellite view of North and South America and adjacent portions of the Atlantic and Pacific Oceans. The photograph was taken from an orbit more than 35,000 kilometers (22,000 miles) above the earth's surface. (NASA.)

Contents

Preface ix

Chapter 1
People and Nature in Conflict 1

PART I
CONCEPTS OF ECOLOGY 5

Chapter 2
Ecosystems: The Flow of Energy
and Materials 7

Components of Ecosystems 7
Movement of Energy 10
Movement of Materials 24
Transfer Rates and Human Activity 35
Transfer Rates and Pollution 36
Conclusions 38

Chapter 3
Ecosystems and Environmental
Change 43

Limiting Factors 44
Ecological Succession 54
Adaptation 64
Conclusions 70

Chapter 4
Population: Growth and
Regulation 77

Population Size 78
Population Regulation 80
Conclusions 100

Chapter 5
The Earth's Major Ecosystems 105

Terrestrial Ecosystems 105

Aquatic Ecosystems	130
Conclusions	144

PART II ENVIRONMENTAL QUALITY AND MANAGEMENT 149

Chapter 6

The Water Cycle 151

A Historical Overview	152
The Hydrologic Cycle	155
The Earth's Water Reservoirs	162
Conclusions	176

Chapter 7

Water Pollution 181

A Historical Overview	181
Drainage Basin Activities	182
Surface Water Pollution	186
Groundwater Pollution	208
Conclusions	212

Chapter 8

Managing Our Aquatic Resources 217

A Historical Overview	218
Legislative Responses	218
Water Quality Control	223
Enhancing the Freshwater Supply	239
Global Water Problems	248
Conclusions	251

Chapter 9

Weather and Climate 257

The Atmosphere: Composition and Structure	257
The Dynamism of the Atmosphere	261
The Changing Climate	274
Conclusions	282

Chapter 10

Air Pollution 287

A Historical Overview	287
Air Pollution and the Quality of Life	288
Air Pollution and Weather	300
Air Pollution Episodes	307
Air Pollutants: Types and Sources	313
Conclusions	318

Chapter 11

Air Quality Management 323

Air Quality Legislation	323
Air Quality Control	326
Compliance: Problems and Progress	333
Assessing the Dollar Cost	336
Conclusions	340

Chapter 12

The Earth's Crustal Resources 345

A Historical Overview	345
Generation of Crustal Resources	347
The Extraction of Crustal Resources	358
Resource Management	365
Conclusions	375

Chapter 13

Waste Management 381

Sources of Waste	381
Toxic and Hazardous Wastes	383
A Historical Overview	385
Waste Disposal Alternatives	387
Solid Waste as a Resource	394
Conclusions	400

Chapter 14

Managing Endangered Species 405

Why Preserve Them?	406
A Historical Overview	411

Contributing Factors	413
Characteristics of Endangered Species	422
Attempts to Save Endangered Species	426
What of the Future?	428
Conclusions	432

Chapter 15

Land Use Management 439

Land Use Conflicts and Control	440
Land Use and Geologic Hazards	450
Conclusions	458

PART III

FUNDAMENTAL PROBLEMS: POPULATION, FOOD, AND ENERGY 465

Chapter 16

Human Population: Growth and Control 467

A Historical Overview	469
Exponential Growth, Age Structure, and Population Momentum	471
Variations Among Nations	476
Population Control	477
The Transition to a Stationary Population	485
What of the Future?	486
Conclusions	488

Chapter 17

Food Resources and Hunger 495

Minimizing Food Losses	496
Cultivating New Lands	502
Increasing Production on Cultivated Land	507
Enhancing the World Protein Supply	520
Harvesting the Oceans	524
Conclusions	526

Chapter 18

Assessing the Energy Crisis 533

A Historical Overview	533
Trends in Energy Use	539
Contemporary Energy Sources and Supply	541
Energy Resource Utilization Policies	567
Conclusions	573

Chapter 19

Averting the Energy Crisis 579

Nuclear Power: Breeder Fission Reactors	579
Nuclear Power: Fusion Reactors	582
Solar Power	582
Tidal Power	600
Geothermal Power	601
Energy Conservation	603
Conclusions	613

Chapter 20

Where Do We Go from Here? 619

Supply Strategies	620
Demand Strategies	622
What You Can Do	623
Epilogue	625

Glossary 627

Appendix I

Conversion Factors 641

Appendix II

The Geologic Time Scale 643

Appendix III

Expressing Numbers as Powers of Ten 645

Index 647

Chapter 1

People and Nature in Conflict

Aldrin, anchovies, and asbestos: what do these seemingly unrelated things have in common? Each in its own way will somehow affect the well-being of many people. Aldrin is a pesticide that contaminates food, anchovies are a major protein source now threatened by overfishing, and asbestos is a valuable mineral that, as an air pollutant, causes lung cancer. These are only three in a perplexing array of serious environmental problems that plague our modern society. With ever increasing frequency, it seems, the media report on some insidious poison that somehow wound up in the wrong place, on a bitter confrontation between conservationists and resource developers, or on a municipality's costly battle to maintain an outmoded waste disposal system. Just where did these problems come from? To find their roots, we must go back many years.

The early settlers of North America found themselves in a land of plenty. Resources were so abundant and the population so small that the government literally gave parcels of land to anyone willing to exploit the timber, fuel, minerals, and running water. And exploit they did, with enthusiasm and thoroughness. They saw no reason not to; the supply of resources seemed endless.

The abundance of natural resources spurred the growth of industry and technology, and gradually a simple, agrarian society became a complex, industrial

one. Smokestacks belching noxious fumes were viewed as beacons of economic prosperity. And the ability of rivers and streams to wash away pollutants was considered more than equal to even the most offensive industrial and municipal wastes.

The growth of industry and prosperity encouraged a steady increase in population, and each succeeding generation demanded more and better products and convenience items and a wider variety of services. Agriculture and industry responded by drawing on increasingly sophisticated technology, which in turn used fuel and materials at an ever accelerated rate. Consumption of energy and mineral resources soared. More water was required to extract resources and produce goods, and in these processes more waste was generated. The nation prospered, but at the expense of environmental quality. Today we enjoy the fruits of our nation's progressive past, but we are also faced with the undesirable by-products of its rapid technological advance.

Many readers, undoubtedly burdened with enough worries of their own, might dare to ask, "But why should *I* worry about it?" The answer is that we all must concern ourselves with the contemporary problems of overpopulation, resource exploitation, and pollution simply because these problems affect every one of us. For example, as our population continues to grow, competition for available jobs

gets stiffer. Well-qualified job applicants find, to their dismay, that their preferred professions and occupations are closed to them simply because the number of people seeking entry exceeds the number of jobs. Also, as our population grows, our demands for certain resources (petroleum, for example) are sometimes not met. Aside from immediate effects (cold homes, stilled cars) such a shortage has serious long-term economic ramifications: as resources are used up, production tails off and with it jobs in manufacturing, sales, and transportation. Resource shortages also contribute to the spiraling cost of living. When resource supply fails to keep pace with demand, scarcity-induced inflation further elevates the prices of goods and services.

Pollution, too, imposes an economic burden on each of us. As the effects of air and water pollution have become better understood, pollution abatement has become more urgent, and governments have responded with strict legislation forcing industries to install expensive air and water quality control devices. Invariably, the cost of these measures is passed on to consumers. To meet water quality regulations, many municipalities must build new sewage treatment facilities. Some construction costs for these plants are covered by federal grants funded by taxes; the rest of the construction costs and all of the operating expenses must be met locally by higher fees for water and sewage treatment or increased property taxes.

But, before we back away from pollution control because of the financial burdens it imposes on us, we must remember the main reason we are concerned about pollution: it directly threatens our personal health. And what price can be put on good health? Although we are making some progress in cleaning up air and water, pollutant health hazards will probably be with us for a long time to come. Most of us may never suffer a debilitating illness as a result of exposure to pollution, but all of us bear an increased risk of becoming ill. Unless we begin to reduce that risk by ridding ourselves of the cause, our legacy to future generations could be one of chronic illness and fear.

When we try to escape our polluted cities by vacationing in the mountains or at the seashore, we meet our neighbors there by the thousands. Our population is so large and mobile that we simply cannot avoid one another. Campgrounds are overcrowded, rural highways are jammed, and even wilderness areas are overrun by people seeking solitude.

Like it or not, then, we are all involved in the problems of population, resource availability, and environmental quality. In facing these issues, we will do well to remember that environmental concern is not unique to our generation. Even in the early days of our nation's industrial growth, some people recognized the connection between health and pollution, and realized that many common exploitive practices were self-defeating.

Awareness eventually spurred some individuals into action. At the turn of this century, a conservation ethic emerged. Efforts were made to protect wildlife prized for hunting, such as deer and waterfowl. Some farmers began to see the merits of protecting cropland from wind and water erosion. Certain timberlands were managed for sustained production instead of being logged over and abandoned. Lands were set aside to preserve their natural beauty and to provide space for recreation. Still, although the conservation movement goes back about a century, major battles against pollution began only recently. In the late 1960s, concern over deteriorating air and water quality gave birth to the environmental movement. Public demonstrations, television programs, and such popular books as Rachel Carson's *Silent Spring* heightened public awareness of the impact of human activity on the environment.

Soon it became politically expedient for legislators to formulate stricter air and water quality laws. The National Environmental Policy Act (NEPA), which requires that an environmental impact assessment be prepared prior to any federally financed project, was passed in 1969. Simultaneously, changes were taking place on a more personal level. Some far-thinking people realized that their lifestyles conflicted with their insights about environmental quality, and they began to make voluntary adjustments. They saw the

advantages of limiting their family size, for instance, and of recycling certain kinds of waste.

In the mid-1970s the Arab oil embargo demonstrated our country's strong dependence on foreign petroleum. Cold homes, long lines at service stations, and closed factories triggered an intense search for alternatives to natural gas and petroleum. And, again, some people began to alter their living habits. They began to trade in their large cars for ones that consumed less fuel. Some two-car families decided that perhaps they could make do with one car, after all.

Today public interest in ecology and the environment has declined. For the most part people seem unconcerned about our energy supplies. One reason for this is that a single issue seldom holds public attention for very long. Another is that significant progress has been made in many areas. The laws we noted here are just a few of the many that have been passed to improve environmental quality.

Yet, despite the progress, many problems remain and new concerns continue to emerge. We have halted the decline in the quality of our air and water, but we have taken only a small step toward returning these priceless resources to their original condition. Nonrenewable resources, including minerals and fossil fuels, continue to dwindle, and we are still using land as if it were in endless supply. Moreover, the fundamental source of our environmental problems remains: our population continues to grow, and so do our individual demands and expectations. Believing that we are still living in an era of unlimited resources, most of us continue to pursue the American dream.

Thus, a great deal remains to be done. What we do today will affect not only our own prospects but also those of future generations. What can we do?

To take constructive action, we must first identify the conflicts. That done, we must consider every alternative and learn enough to analyze the consequences of each. Although many environmental problems are formidable, solutions do exist. For example, it is true that petroleum supplies are falling behind demand, but vast supplies of coal and alternative energy sources (solar, wind, and geothermal) have

yet to be tapped. Also, we have a vast storehouse of knowledge from which to develop solutions; and history warns us against underestimating human ingenuity.

On the other hand, we must recognize that we are working under severe constraints. For example, using more coal will accentuate air pollution, and more air pollution will increase the health hazards. Also, developing new technologies is expensive, and the amount of money we can afford to spend on air pollution control is limited.

Everyone is affected by environmental problems, and therefore everyone has a stake in (if not a personal responsibility for) solving them. But our collective success depends on how much we know and how creatively we apply our knowledge. In forthcoming chapters, we will explore topics that will provide the reader with a rational basis for deciding our environmental future. First we will examine how nature works and the many ways in which it serves us. Then we will consider how our activities affect the proper functioning of these natural processes, which in turn influence our own well-being. After examining the roots of our problems with population, resources, and the environment, we will explore current attempts to correct them, analyzing the results to date, both the benefits and the costs. Finally, we will consider what the future may hold for us.

It will be clear from these discussions that for every problem we identify many responses are possible. Some readers may decide that these issues are unimportant and may choose to do nothing. Others, believing the problems to be critical, may decide to devote their lives to solving them. Most of us will probably take a position somewhere between these extremes. The choice we make will hinge on our knowledge, our personal prejudices, and our ideals.

Challenging days are ahead. Many futurists predict that major changes will take place, not all of them welcome. But only by making the proper decisions can we hope to direct our own destinies. We are at the crossroads now, and a sense of purpose anchored in understanding has never been more important.

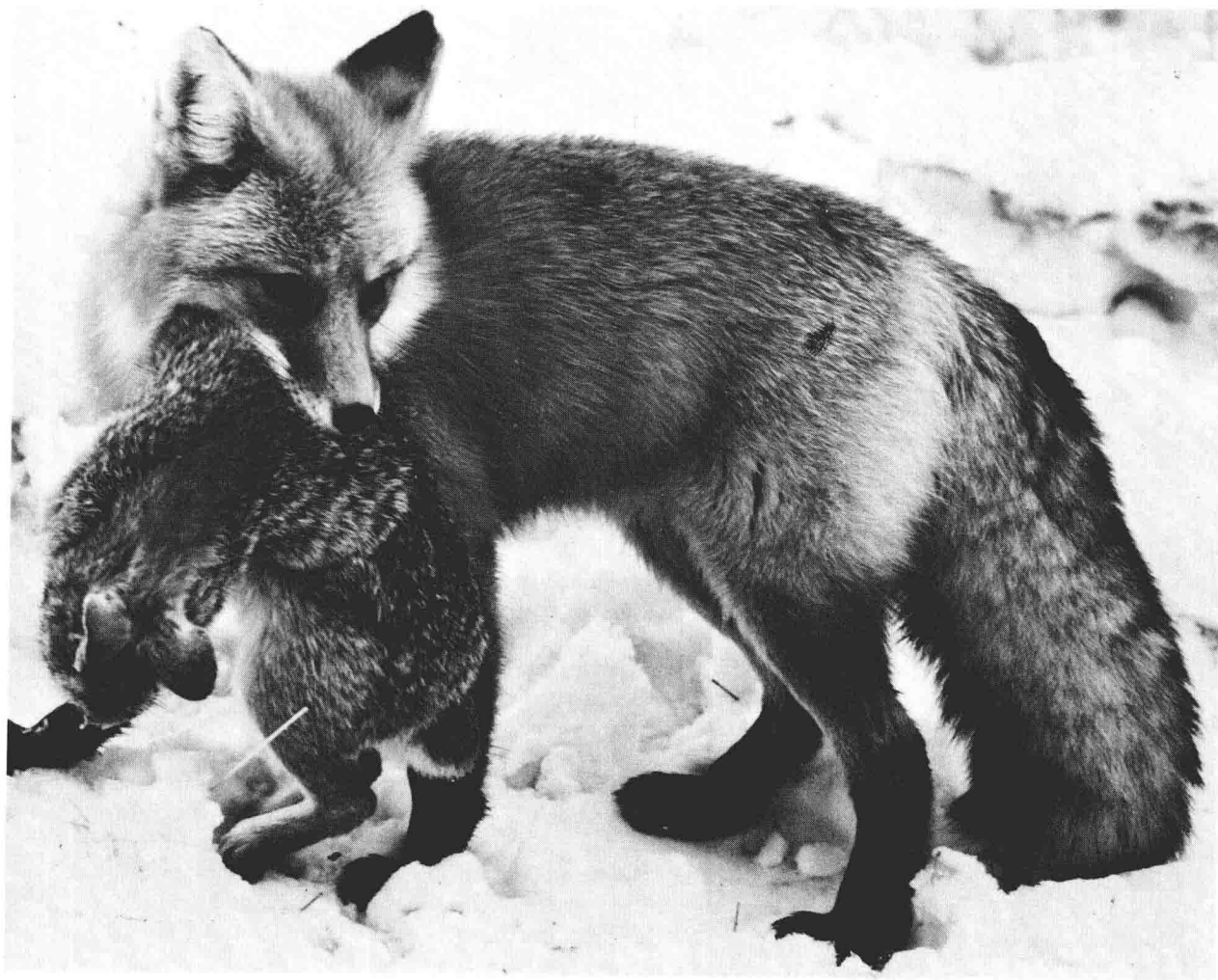


Part I

Concepts of Ecology

To find practical answers to environmental problems, we must first understand how the environment works. In this part of the book, we consider some of the fundamental principles that govern nature's activities. In Chapter 2, we look at the flow of energy through food webs and the movement of materials through the environment. An understanding of these flows is essential to the solution of such problems as human hunger and the decline in the quality of our air and water. Because the environment is constantly changing, either naturally or as a consequence of human activities, we consider in Chapter 3 the response of organisms and ecosystems to such factors as water and air pollution, fire, weather, and agriculture. In Chapter 4, we look at how populations grow and at what controls their growth. Only by understanding population growth can we control the pests that attack our crops and livestock, thwart some of the organisms that transmit human diseases, save certain endangered species, and limit human population growth. In Chapter 5 we consider the characteristics of the diverse ecosystems of the earth and the points at which these ecosystems are vulnerable to human activity.

In succeeding sections of this book, our understanding of the basic principles that govern the working of the environment will help us to better understand the environmental consequences of human activities. As our increasing numbers and activities continue to have an impact on the earth, a better understanding of ecological principles becomes ever more important to our well-being.



This fox, carrying its prey, vividly illustrates one step in the flow of energy through an ecosystem.
(Wilford L. Miller, from National Audubon Society.)

Chapter 2

Ecosystems: The Flow of Energy and Materials

Opinion may differ as to which of our environmental problems are the most critical, but most of us probably share many of the same concerns. We worry about the pollution of our air and water. We fear that we will run short of fuel to drive our cars and heat our homes. Some of us are angered about plans to build a new highway through farmlands or to develop a waste disposal site in our neighborhood. Basically, such concerns are rooted in the fact that most of our resources are limited—when demand exceeds supply someone suffers from the shortages.

On a larger scale too, all of our environmental problems are economically and ecologically interrelated: each one has resulted from the inability of the environment to maintain its integrity in the face of our unrelenting demands for more material goods. Each of our environmental problems involves the movement of energy and materials through the environment, and this movement is governed by certain inviolable principles that we all too often forget to take into account. In our disregard of these principles, we simply try to make nature do more than it can do.

Components of Ecosystems

To understand the laws that govern the movement of materials and energy in the environment, we will study these flows in the framework of *ecosystems*. An ecosystem is a functional unit of the environment that includes all organisms and physical features within a given area. An ecosystem thus consists of both living, or *biotic*, and nonliving, or *abiotic*, components. The biotic community is made up of *producers* and *consumers*, which are distinguished by their major functions. Producers, mainly green plants, manufacture their food from water and carbon dioxide, using sunlight as a source of energy. (This process is called *photosynthesis*, and it is discussed further in subsequent paragraphs.) In contrast, consumers are incapable of producing their own food, and must consume other organisms for energy and nutrition.

Consumers fall into one of four classes on the basis of their food source. A consumer that eats only plants is a *herbivore*, whereas a consumer that eats only animals is a *carnivore*. An *omnivore* eats both