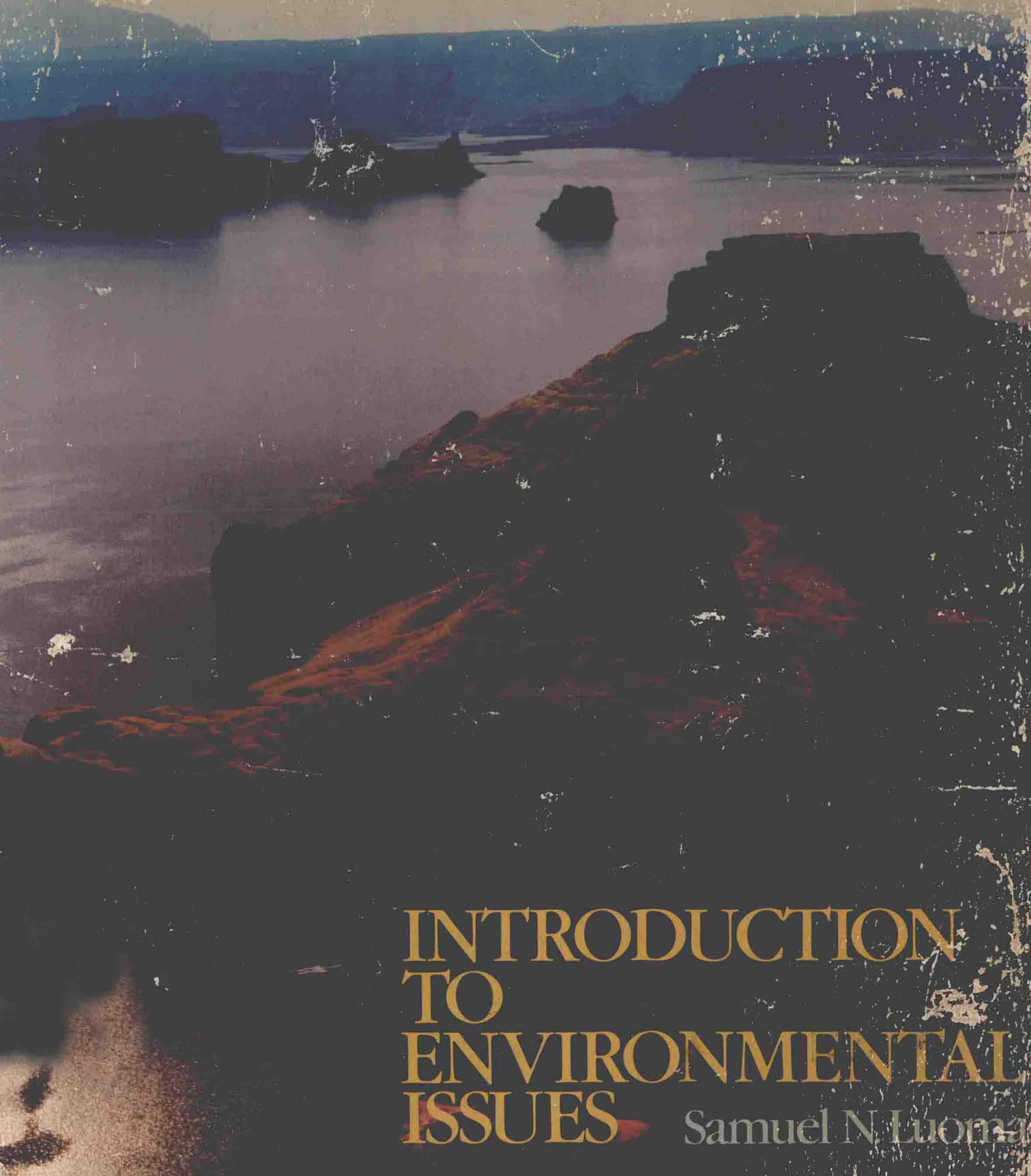

INTRODUCTION TO ENVIRONMENTAL ISSUES

Samuel N. Luoma

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ENVIRONMENTAL ISSUES

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PREFACE

This book is written for beginning students of the science of the environment. Its primary goals are to present a balanced view of the diversity of issues that relate to the environment and to provide the fundamental information that will allow students to understand the complexities of those issues. Recognition of complexity and rigorous emphasis on balanced analyses are essential ingredients in resolving environmental problems. My goal has been to emphasize both in this study of environmental issues.

Every environmental issue has characteristics that make simple solutions unrealistic. Most issues are technically complex and multidisciplinary in nature, span time scales longer than those considered in many policy decisions, and involve conflicts among engrained cultural value systems. Because of the complexity involved, knowledge of nearly every environmental issue is incomplete. Thus, policy decisions and personal political choices require value judgments. Even if the scientific basis of an issue were well resolved, it is likely that value judgments still would be necessary in environmental decison making, because conflicts of cultural values never can be resolved from scientific facts alone.

It is important to recognize, however, that the political philosophy of environmentalism is distinct from *environmental science. Environmental science* is the *scientific* study of the structure and function of all environmental systems, of their interactions among themselves and with human cultural systems. The goal of the environmental scientist is to acquire knowledge. By definition, environmental science does not involve advocacy of any specific value system but is the information base from which different advocacy positions are established.

Although scientific knowledge cannot be the sole basis of resolving environmental issues, those issues will not be resolved without scientific input. Only through scientific study can the complexities of each issue (or the sum of all issues) be understood. To deny those complexities is to deny reality. Among other things, study of the science of the environment helps identify issues of importance (albeit, "importance" involves subjective judgment); it may help order the priorities of issues (essential in a complex world where everything cannot be done at once); it helps focus questions on the critical components of issues; it helps in predicting the effects of alternative solutions or strategies; it helps anticipate the emergence of issues in advance; and it provides the knowledge from which solutions to problems are built. Even though our knowledge base is incomplete, the need to understand environmental science is obvious, no matter what one's political philosophy about the environment.

In the past much of the environmental debate has involved advocacy alone, with all sides simplifying complex issues and avoiding balanced analyses, presumably for fear of losing political support. Our knowledge of environmental systems is becoming increasingly sophisticated, however. Although complete answers to environmental questions are still rare, the factual basis of some problems, the critical aspects of some specific issues, and even potential realistic strategies for solution of some problems have become increasingly clear. For example, we now know that escalating human popula-

tion growth is not a global phenomena but is focused in poor countries. It appears that slowing that growth is strongly related to improvements in human well-being, especially for women. We are beginning to understand both the strengths and the limitations of the modern agricultural revolution. Only consideration of population growth and the agricultural revolution will allow us to develop a sustainable system for providing human food. We are beginning to recognize what types of material resources are likely to limit the growth of economic systems and the specific costs and benefits of different energy systems. We are beginning to understand the workings of the ecological systems that support life on earth and how human activities affect those systems (in a general sense). We also are developing an understanding of the interaction of human health and environment, and why we sometimes cannot expect complete understanding of those processes.

Another goal for this text is to focus on underlying principles and the exciting advances in understanding that have characterized the last decade of environmental science. This focus will provide the base for a discussion that will analyze all sides of each issue, present alternative viewpoints, and study the differences between those views. This approach should help each student establish a base of general knowledge about environmental issues from which rational, educated political choices and opinions can be fashioned independently.

An environmental science text can be organized in a variety of ways. The chapters of this book (and especially the sections) have been written to stand as independently as possible. If an instructor prefers an organization different from that used here, the text should be amenable to such changes. The organization chosen starts with a general explanation of environmental systems and how they are studied. Chapters 2 through 5 deal with the cause of the problems of the environment: population growth and the development of our modern cultural system. The chapters that follow deal with the problems themselves. The issues associated with human modification of the biosphere are discussed in Chapters 6 through 13. Chapters on resource issues follow, including assessments of food production (Chapters 14 through 16), material resources (Chapter 17) and energy (Chapters 18 through 21). The Epilogue links the major interactions among the various issues.

The literature references (author's name and date) that appear in the text refer to the reference list at the end of the book. The references there are listed in alphabetical order by author's name and chapter number, in order to provide a comprehensive list of available source materials in general subject areas. Most references are from readily accessible publications.

The book uses only metric units, but conversion scales can be found inside the front cover.

S. N. L.

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Charles Wilber, Colorado State University

S. N. L.

NOTE ABOUT THE AUTHOR

The author was born and raised in Montana and received his Bachelor and Master of Science degrees from Montana State University in Zoology in 1968 and 1970, respectively. He completed his doctorate in Marine Biology at the University of Hawaii in 1974. He has taught biological and environmental science courses at the university level in Hawaii and California, and has employed his expertise in ecology, physiology, chemistry, and hydrology as a university researcher, as a professional consultant, as a research fellow in Europe, and as a research project leader with the United States Government. He is presently employed as a research project chief with the United States Geological Survey in Menlo Park, California. The author has published nearly forty articles in technical journals and symposia prior to this book. His research primarily considers chemical and biological aspects of water quality and the fate and effects of toxic materials in aquatic environments. His work in Europe, Hawaii, and throughout the western United States, plus his upbringing in Montana, have contributed to a lifelong interest in the diverse array of environmental issues considered in this book. All views presented in the book are those of the author and in no way reflect the policies of any employer.

CONTENTS

1 INTRODUCTION 1

The Issues 1
Environmental Science 4
Systems Behavior 5
The Environmental System 10
The Development of Environmental Systems 12
Analyzing Environmental Issues 18
Appendix: Statistics in Environmental Science 22
Summary 24
Review Questions 25
Suggested Reading 25

2 POPULATION ECOLOGY 27

Population Density 28
Population Dynamics 35
Ecologic Principles and Modern Human Demography 46
Summary 48
Review Questions 48
Suggested Reading 50

3 DEMOGRAPHIC TRANSITION IN DEVELOPED COUNTRIES 51

The History of Human Populations 51
Phases of the Demographic Transition 55
Alternatives to the Demographic Transition 73
Summary 74
Review Questions 74
Suggested Reading 75

4 POPULATION GROWTH IN THE LESS DEVELOPED WORLD 77

Characteristics of Populations in LDCs 78
Social Setting 83
Family Planning 96
What Causes Fertility to Decline in Poor Countries 99
Age-Structure Momentum 105
Summary 106
Review Questions 107
Suggested Reading 108

5 POPULATION GROWTH AND ECONOMIC DEVELOPMENT: THE ENVIRONMENTAL DILEMMA 109

Accuracy of Population Projections 110
Possible Changes in Present Demographic Trends 110
Specific Population Projections 113
The Environmental Dilemma 115

Summary 116
Review Questions 116
Suggested Reading 117

6 INTERACTIONS OF THE CULTURAL SYSTEM AND THE BIOSPHERE 119

The Biosphere and Biogeochemical Cycles 120
The Human Role in Biogeochemical Cycles 123
Assimilation Capacity: Natural Corrective Mechanisms 126
Overwhelming the Assimilation Capacity 131
Case Study: DDT 135
Summary 137
Review Questions 138
Suggested Reading 138

7 FOOD WEBS IN NATURAL AND MODIFIED COMMUNITIES 139

Photosynthesis and Respiration 140
Food Chains 143
Summary 156
Review Questions 156
Suggested Reading 157

8 MECHANISMS OF ECOSYSTEM SIMPLIFICATION 159

Development of Complexity 160
Types of Species in Ecosystems of Different Complexity 169
Human Effects on Community Structure 175
Examples of Human Simplification of Ecosystems 176
Summary 180
Review Questions 181
Suggested Reading 181

9 CAUSES OF THE CULTURAL SIMPLIFICATION OF ECOSYSTEMS 183

Physical Degradation of Habitat 184
Discharge of Toxic Materials 196
Oil: A Case Study in Toxicant Behavior 199
Nutrient Enrichment 203
Summary 210
Review Questions 210
Suggested Reading 211

10 WHY PRESERVE BIOLOGICAL COMPLEXITY? 213

The Value of Ecosystem Complexity 214
Strategies for Conservation 222
The Sum of All Arguments 224
Summary 224
Review Questions 225
Suggested Reading 225

11 CLIMATE 227

The Climatic System 227
Climatic Variability 233
Human Effects on Climate 239
The Future 247
Summary 249
Review Questions 250
Suggested Reading 251

12 EFFECTS OF WASTES ON HUMAN HEALTH 253

Assessing Effects of Pollutants on Humans 254
Categorizing Pollutants 260
Infectious Disease 261
Noncumulative Chemicals 263
Cumulative Toxins 264
Carcinogens, Teratogens, and Mutagens 275

Summary 283
Review Questions 285
Suggested Reading 285

13 AIR POLLUTION 287

General Health Effects 288
Types of Air Pollution 291
Trends in Air Pollution 303
Stratospheric Ozone 305
Summary 310
Review Questions 311
Suggested Reading 311

14 CHARACTERISTICS OF MODERN AGRICULTURE 313

Development of Modern Agriculture 314
High-Yield Crop Varieties 316
Nutrient Control 321
Water Control 323
Pest Control 329
Mechanization 338
Economic Infrastructure 341
Summary 344
Review Questions 344
Suggested Reading 345

15 FOOD: DEMAND, SUPPLY, AND SOLUTIONS 347

Demand and Supply: Recent History 347
Nutritional Status 350
Demand 352
Food Supply 357
Balancing Supply and Demand 376
Summary 378
Review Questions 379
Suggested Reading 379

16 FOOD FROM AQUATIC ENVIRONMENTS: FISHERIES AND AQUACULTURE 381

Fisheries 381
Aquaculture 398
Summary 406
Review Questions 407
Suggested Reading 407

17 PRINCIPLES OF RESOURCE EXPLOITATION 409

Nonrenewable Resources 410
Resource Depletion 410
Human Ingenuity 415
Abundant and Scarce Materials 416
Estimates of Reserves 425
Understanding Resource Controversies 428
Summary 428
Review Questions 429
Suggested Reading 429

18 ENERGY: FOSSIL FUELS 431

Petroleum 433
Natural Gas 443
Coal 445
Synfuels 449
Fossil Fuels in the Future 452
Summary 453
Review Questions 454
Suggested Reading 454

19 NUCLEAR POWER 455

Nuclear Technology 455
Areas of Controversy 459
Summary 474
Review Questions 475
Suggested Reading 476

20 ENERGY SOURCES OF THE FUTURE 477

Renewable Energy Sources 478
Hydroelectric Power 479
Direct Solar Conversion, Wind, and Ocean Thermal Energy Conversion (OTEC) 479
Biofuels 488
Geothermal Energy 494
Fusion 495
Diversity in Future Energy Strategies 498
Summary 498
Review Questions 499
Suggested Reading 499

21 RESOURCE DEMAND 501

Ingredients in Resource Demand 502
Economic Growth and Resource Demand 503
Projecting Demand for Resources 507
Balancing Demand with Supplies of Energy 517
Summary 520
Review Questions 521
Suggested Reading 521

EPILOGUE 523

REFERENCES 531

INDEX 545

1

INTRODUCTION

THE ISSUES
ENVIRONMENTAL SCIENCE
SYSTEMS BEHAVIOR
  Inputs, Outputs and Feedback
  Complexity in System Behavior
  Laws of Thermodynamics
THE ENVIRONMENTAL SYSTEM
  Physical System
  Biologic System
  Cultural System
THE DEVELOPMENT OF ENVIRONMENTAL SYSTEMS
  Evolutionary Development of the Earth
  The Modern Cultural System
ANALYZING ENVIRONMENTAL ISSUES
  Statistics
  Assessing Risk in Environmental Issues
    Eliminating False Hazards for the Sake of Economic Benefit
    Eliminating Mistaken Exposures
  The Political Choices
APPENDIX: STATISTICS IN ENVIRONMENTAL SCIENCE
SUMMARY
REVIEW QUESTIONS
SUGGESTED READING

The preface briefly defines the strategy and philosophy of this text. Before beginning this discussion of environmental systems, students are encouraged to read that short section.

THE ISSUES

The problems which define environmental issues all involve the interactions of human culture with the environment within which humans must live on earth. Debate about environmental issues has arisen because of the increasing perception that the human cultural system is growing at a rate that threatens its own welfare and the welfare of other biologic systems on earth. Human populations have grown to sizes that challenge economic well-being, social and political stability, environmental integrity and the abilities of the cultural system to provide the essentials of life for all—food, clothing, shelter, and fuel. One in every four people on earth must struggle to obtain enough to eat. The biologically richest forests on earth are being decimated as poor people struggle to obtain enough fuel to heat their shelters and cook their food. The very bases of the agricultural production of food appear to be eroding as people in poor countries are forced to farm steeply sloping lands and wealthy nations continue policies and practices that degrade and consume useful lands. Production of suffi-

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cient food for the present population of the world has become tied to high-yield agricultural technology. Questions about how long that strategy can be sustained increasingly arise.

The human cultural system also has become highly efficient at producing energy, goods, and services that people in wealthy nations consider necessities and people in poor countries strive to obtain. These include electricity, automobiles, mass communication systems, and an array of appliances and machines to assist in arduous tasks. Industrial and manufacturing enterprises have grown to the point where they challenge the cultural system's ability to find and extract the earth's resources necessary to produce such goods. One of the most economically important of nature's resources—petroleum—has shown the initial signs of an impending shortage. Supplies of industrially critical minerals are increasingly restricted to fewer countries as initial supplies are depleted. As necessary material resources dwindle, the potential grows for international conflict that could literally destroy human civilization.

The issues of population and industrial growth are complicated by the uneven distribution of problems over the earth. The 25 percent of people in the world who live in developed countries consume ten times more energy, ten times more food, and many more material resources per person than do the people of poor countries. Population growth, massive unemployment, and food shortages are largely problems in the poorer, less developed nations of the world (where 75 percent of the people on earth live). Solutions to these problems appear to involve improving the socioeconomic welfare of all citizens of poor countries and expanding high-yield agricultural technology in those countries.

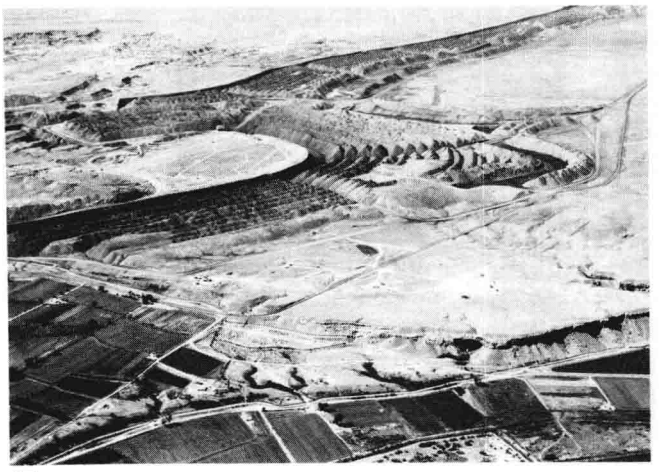
The largest supplies of many of the raw resources necessary to sustain the economic systems of the world are located in the poor nations. Most of these resources are being consumed by the wealthy nations and small wealthy classes of the poorer nations. Nearly all analysts agree that mobilizing sufficient money, energy, and material under present resources to allow the majority of people in the less developed world to achieve an overall standard of living similar to that of the developed world is a nearly impossible task under present distribution systems. On the other hand, it is difficult to envision continuing peaceful coexistence in a world where people living in luxury satisfy their needs at the expense of civilizations drowning in poverty and associated problems.

The focus of the preceding issues is on how our cultural system might exploit the environment to subsidize human survival. Many of the problems are technological. Past civilizations have found solutions to such problems. Thus, a precedent exists to suggest that human ingenuity can provide the needed solutions. These cultural issues compose only one half of the environmental issues, however—perhaps the easiest half to solve. Humans have had less experience and less history of success with the rest.

The second set of issues deals with how human exploitation of the environmental system affects the system itself. There is no question that the activities of hu-

(Opposite) Major environmental issues involve the interactions of populations, environment and resources. (a) Where the human cultural system dominates, species disappear. The world of concrete, asphalt, and buildings offers little suitable habitat for species other than *Homo sapiens* and those few organisms that exploit the wastes of human civilization. [Photo courtesy Pacific Gas and Electric.] (b) A strip mine on agricultural land in the western United States. Demand for resources, food and environmental conservation often conflict. [Photo by Harvey Mudd, courtesy Friends of the Earth.] (c) Poverty in the less developed world is a major stimulant of population growth. [Photo courtesy Friends of the Earth.] (d) A market in Guatemala. Provision of adequate food for people in poor countries requires food prices high enough to stimulate productivity by farmers but low enough to be affordable to the masses of urban poor people. [Photo by James A. Davis.] (e) An oil field in the Caspian Sea. The resource most important to modern economies, petroleum, is showing the initial signs of depletion. [Photo by S. Kulishoo, courtesy Friends of the Earth.] (f) The solutions to many cultural problems conflict directly with solutions to environmental problems. [Photo by Elihu Blotnick, courtesy Friends of the Earth.]

(a)



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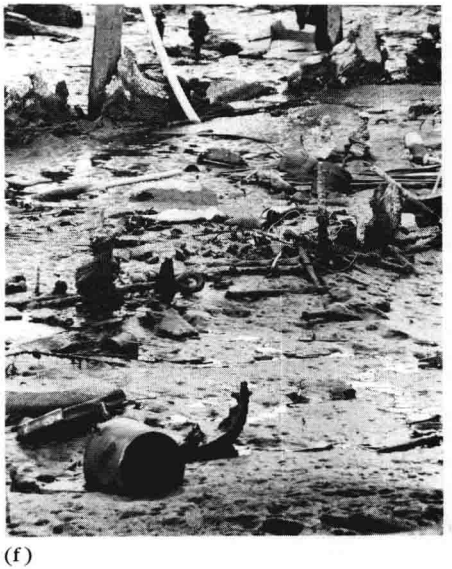

(f)

man society are measurably changing the environment of the earth. Some of those changes are obvious and visible. Agriculture and urbanization intentionally change the characteristics of the ecosystems they invade. Waste discharges accomplish the same results, but with less intention. Wherever human civilization expands, species disappear; chemical measurements show detectable changes in the characteristics of air, water, and soil; and the physical nature of land forms and waterways are visibly altered. Some changes in environmental characteristics are global in magnitude. More commonly, the changes are local, so that the earth resembles a mosaic of physical and biologic systems changed to a lesser or greater extent by human culture.

Resolution of cultural environmental issues appears to conflict with resolution of problems of environmental modification. Deforestation of biologically rich tropical forest communties, soil erosion, water pollution, and degradation of urban air quality are a few of the unavoidable prices physical and biologic systems must pay as growing populations in poor nations search for fuel and food. There is no cultural precedent for bettering human welfare in poor nations without accelerating the rate of environmental modification. Providing food for the populations expected in 2000 or 2020 could involve intensively farming nearly every arable hectare on earth. This will require a massive, intentional global simplification of the biological system, redirecting four billion years of developmental momentum within one half a century. Coal and synthetic fossil fuels, the most promising solutions to the energy problem, threaten to change the climate of the earth (perhaps at rates that have historically contributed to the downfall of civilizations). They also threaten the quality of surface and ground waters and human health. Materials crises have been resolved in the past by substitution and innovation. The invention of 100 to 1,000 new chemicals annually is necessary to satisfy the growing demands for new materials. Without a massive commitment to research and testing, however, we cannot hope to ascertain the safety of each of those chemicals before they are put to use. Yet, when those materials appear as waste products of civilization, the result has been an unintentional threat to the survival of key species; contamination of species used as food resources; and potential and perhaps unidentifiable threats to the health and welfare of the member of the biologic system of most concern to us, *Homo sapiens*. The final solution to the problem of environmental modification could involve slowing economic growth—a prospect that seems likely in the developed world anyway. But in a steady-state economy committing the economic resources necessary to slow the effects of environmental modification may not be the first political choice of people confronted with more immediate and more visible problems.

The second set of issues then involves asking, whether we, as but a single component in the complex, unique, and beautifully functional environmental system, have the right to modify the system drastically to meet our own selfish needs. From an anthropocentric point of view we must ask if our civilization can survive rapid modification of the system to which we owe everything that we are.

The dilemma is that each environmental issue, if confronted by itself, could probably be resolved. Finding the time, money, energy, food, and resources to solve all cultural issues simultaneously is a much greater challenge. However, the challenge pales beside the immensity of the challenge to simultaneously deal with cultural issues and physical, biologic, and human health issues, the resolution of which seem to conflict at every turn. Humans have long been impressed with their abilities to accumulate the type of knowledge that leads to ingenious solutions to seemingly intractable problems. However, at few times in our past have we faced problems as difficult as the suite of environmental issues we will have to confront in the decades ahead.

The following chapters will study the issues of population, environmental modification, and resource availability in turn. In the remainder of this chapter we will consider the basic characteristics of our interacting environmental and cultural systems and discuss some of the difficulties in analyzing the scientific issues concerned.

ENVIRONMENTAL SCIENCE

The science of the environment draws on information from nearly every biologic, physical, chemical, and social discipline. Environmental science, however, is more

than a "synthetic gathering of the fruits of other established disciplines."* It is the study of the functioning of environmental *systems.* Its uniqueness lies in a holistic, systems view of the complex interactions among disciplines—a view that includes not only the study of structure and function in ecosystems, but must include social, economic, and cultural influences on the biosphere and physical, chemical, or biologic influences on social, economic, and cultural processes.

In this chapter the general rules of systems behavior will be described before the environmental system is described. The goal is to establish a picture of the environment and environmental issues that will encourage the reader to maintain a holistic view when individual issues are discussed in later chapters.

SYSTEMS BEHAVIOR

The study of systems behavior relates to the study of the environment as a whole and to the study of specific environmental issues. Within the global environmental system many small systems exist, but all follow many generally similar rules.

Inputs, Outputs, and Feedback

A system is a discrete entity that can be characterized by quantifiable inputs and outputs to a *reservoir* (for example, inputs and outputs of energy or matter in the case of an *ecosystem,* of energy or money in the case of an *economic system,* or of people in the case of a *population*).

If input rates exceed output rates the reservoir grows. If output rates exceed input rates the reservoir shrinks. If the two rates are in balance, the reservoir maintains a constant size (no matter what the *magnitude* of the rates) and the system is at *steady state,* or dynamic, equilibrium (Figure 1–1). A change in either input or output, of course, is rapidly reflected in an internal readjustment of the system, usually toward a new steady state.

The size of the inputs and outputs compared to the size of the reservoir determines the *residence time* of material in the reservoir. If inputs and outputs are large, the residence time is short, and material or energy will *turn over*—that is, be replaced—rapidly. If inputs and outputs are small and the reservoir is large, the opposite will be true.

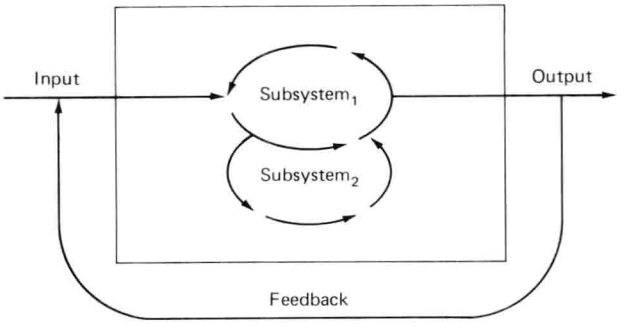

FIGURE 1–1. Simplified schematic diagram of a system indicating inputs, outputs, and feedback. Arrows show flows of materials, energy, or money.

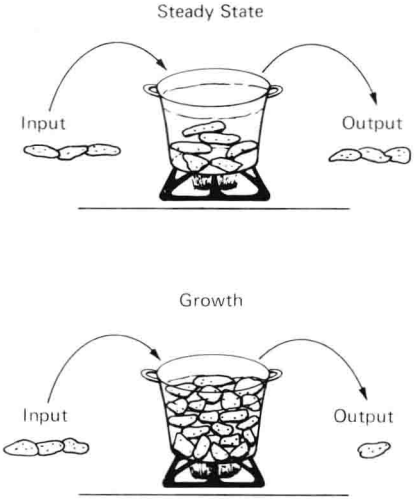

FIGURE 1–2. Illustration of how input and output affect the internal state of a system using potatoes in a pot. If three potatoes are taken out every time three potatoes are added, the number of potatoes cooking will remain constant—a steady state. If only one potato is removed when three are added, the number of potatoes cooking will grow. Eventually a critical resource (in this case, space in the pot), will be depleted, and we will no longer be able to add potatoes to the pot.

* A paraphrase from an anonymous, but valuable, review.

TOMORROW'S MARKET DEMAND FOR ENVIRONMENTAL SCIENTISTS

By Odom Fanning

The Bureau of Labor Statistics has projected 13.5 million college graduates for the decade of the 1980s, but only 10.2 million openings in traditional jobs. This means that one in four graduates will be required to settle for a lower-skill job than desired.

The optimistic way to look at such a future is to ask: "Even under the circumstances, three out of four will compete successfully. How can I maximize my chances in the competition?"

Almost anyone can maximize the chances for career success by pursuing a broad, liberal arts undergraduate curriculum; getting as much advanced education as intellectual and financial resources permit; combining study with practical work experience; and finding and focusing on a potentially expanding area of science, management or professional practice.

Of all the new fields that opened up and expanded rapidly in the 1970s, environmental science and its applications, more than almost any other, provided a large market demand of job opportunities into the 1980s—and promises to continue to do so into the 1990s.

The decisionmaking called upon to solve environmental problems is not something that can be turned over to sophisticated electronic devices, robots or even skilled technicians. It can be performed only by qualified scientists and engineers, supported by paraprofessionals such as technicians, and managers working in interdisciplinary teams.

Environmental science is *interdisciplinary* (one science interacting with others); *integrated* (the sciences combined with arts and humanities); and *involved* with people (knowledge applied to solving pressing social problems).

As an environmental scientist, you would be concerned with ends as well as means, applying knowledge to practical purposes. The range of those problems, as well as the types of curricula to prepare for dealing with them, is suggested by some of the key interdisciplinary environmental science areas: *The Earth Sciences; The Sciences of Living Things; Environmental Health; Resources and Recreation;* and *Land Use and Human Settlements.*

The number of variables introduced into such a complex interaction makes projecting market demand—for people, products or money—extremely difficult. Yet, investigators and futurists continue to make the effort. For example, working under a grant from the National Science Foundation, researchers (1982) anticipated openings in engineering and the physical sciences, by 1992, to be:

> sufficient to absorb all of the expected doctoral graduates, the master's graduates, and some portion of the bachelor's graduates.
>
> Job openings for math and computer professionals will exceed the total of all degrees awarded at all levels.
>
> In the life and social sciences, the openings should be able to absorb the Ph.D.'s and some of the master's graduates, but few or none at the bachelor's level.[1]

[1] *Opportunities in Science and Engineering: A Chartbook Presentation,* by Betty M. Vetter. Washington, D.C.: Scientific Manpower Commission, 1982.

The same study found wide variations by discipline as well as amount of higher education. Geophysicists, for example, will be much in demand, and chemists and geologists with graduate degrees should find openings; but physicists will be "somewhat oversupplied." (As many national and international policies and events around the world certainly will influence U.S. workforce trends, all such statements could be wide of the mark.)

My own studies over recent years predicted growth in environmental science and technology from half a million identified professional and paraprofessional workers at the end of the 1960s, to more than a million by the mid-1970s, to 1.75 million by the mid-1980s.[2] Such rapid growth could not long continue. (There are a number of reasons; importantly, younger persons attracted to the new openings tended to stay, and turnover was modest.) Consequently, I foresee a slowing of environmental science employment to a level of about 2 million by the mid-1990s. (Even so, the growth has been unprecedented.)

I do not hesitate to encourage today's student to become an environmental scientist, especially considering the personal satisfaction one can find therein. The American people (and those in other developed, and many developing, nations) continue to demonstrate a deep commitment to environmental enhancement. We express this commitment in public opinion polls, elections, and the ways in which we make myriad private and public decisions and purchases, from automobiles to forests and pollution programs.

The U.S. Council on Environmental Quality estimates that this nation will spend, by the mid-1990s, more than half a trillion dollars to achieve environmental goals. Such an expenditure would, in itself, create a tremendous market demand for qualified environmental scientists.

(*Note:* Odom Fanning is a Washington-based journalist on consumer and environmental affairs who has published three books and some fifty articles on environmental careers. Formerly a federal official, he helped to develop the major national environmental programs, and edited *The First Annual Report on Environmental Quality* of the President's Council on Environmental Quality.)

[2] *Opportunities in Environmental Careers,* by Odom Fanning. Lincolnwood, IL: National Textbook Co., 1973; ed ed., 1982.

Imbalances in inputs or outputs cannot go on indefinitely. No reservoir can decline in size indefinitely without disappearing, ultimately. Similarly, no system can grow forever without reaching the limits of some *resource* on which it depends. (A resource is anything, matter or energy, essential to the survival of the system.) Thus, systems must have built-in mechanisms that promote stability and drive the system toward a steady state when differences between input and output occur. The most common of these mechanisms is *feedback.*

Feedback occurs when information about the condition of a system is used to control the input or output of the system. *Negative feedback* occurs when a deviation in the system in one direction leads to a corrective reaction in the opposite direction. If the response to noticing that the pot of potatoes is filling in Figure 1–2b (a change in the system) is to reduce the number of potatoes being added to the pot (an opposite change in input), negative feedback has been used to stabilize the system.

Feedback reactions that promote *instability* also can occur. In these *positive* feedback reactions a deviation in the system leads to a change that causes the deviation to *increase.* A simple example is the use of some pesti-

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