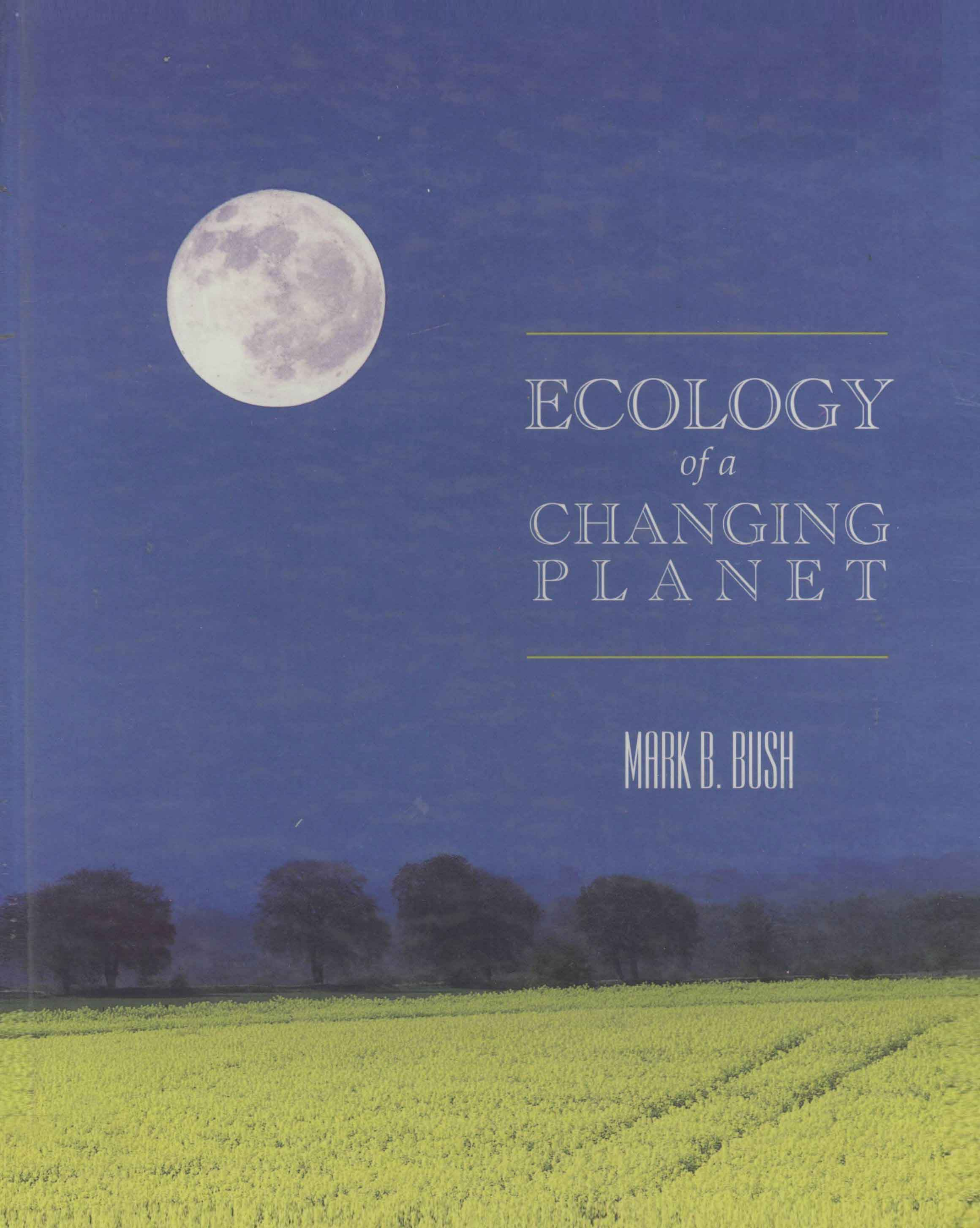

ECOLOGY *of a* CHANGING PLANET

MARK B. BUSH

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Preface

Teaching and writing are the closest most scientists come to performance art. At its best, teaching is truly interactive. New ideas presented enthusiastically stimulate interest and provide a learning experience for both student and teacher. Writing a textbook is, in many ways, similar. I have learned much as I researched these chapters, frequently heading from the keyboard into the classroom to try out a new line of thinking on my students. Hopefully, some of my enthusiasm shines through in the text. A textbook is no substitute for an effective teacher, but it should be a valuable ally to teacher and student alike, providing a common baseline of knowledge. I believe that a textbook should be topical, relevant, and interesting to read. Although scientists must learn facts, I have tried to emphasize the concepts and examples of applied ecology, rather than produce an encyclopedia of indigestible statistics.

My goal has been to write an introductory applied ecology text that centers on how ecology relates to environmental issues. Although many teaching variations are possible, I have written the material in the sequence that I teach it. The first half of the book establishes a strong framework of applied ecology. The second half of the book develops environmental issues such as habitat fragmentation, acid deposition, and the emergence of new human diseases. Each topic is investigated from a scientific rather than an activist viewpoint and is written to stand alone. This book is meant for students who have had a college-level introductory biology class and want to pursue biology, ecology, or environmental science to the next level.

To the student:

Science requires precision of measurement, careful thought, and recall. It is often said that a little knowledge is a dangerous thing. It is not enough to grasp only the "big picture." Facts are used to support an argument, and it is essential that you understand how the details relate to larger concepts. Misinformation about the environment occurs when these details, conveniently or accidentally, are ignored. The natural world is incredibly complex and full of detail. In this book I have distilled, from all this information, what I believe to be the essentials for an introduction to applied ecology.

To get the most from this book or a course in ecology, try to think like an ecologist. Nature is all around us as we walk between buildings, drive down the road, or stare out of a window. Can you explain what you see? What does the news have to do with ecology? New disease outbreaks, wars, refugees, famines, an oil-spill, a new medicine to combat malaria, a hydroelectric project stalled by concern for an endangered species are all going to have ecological and environmental impacts. Be informed.

In writing this book, I have concentrated on presenting scientific arguments relating to environmental issues rather than encouraging environmental activism. Make your own judgment. Use your knowledge of ecology to determine what needs to be done to the environment. Then talk to others, including your instructor, about how to achieve it. It's your Earth!

To the instructor:

I have found the content of this book to be a successful blend of material for teaching an introduction to applied ecology and for heightening environmental awareness. In my class, I try to maintain some emotional distance from the issues, but I encourage my students to become active. Internet home pages of such organizations as the Sierra Club, Envirolink Network, Defenders of Wildlife, and federal and state governments can be monitored by the students. These addresses can be found in Appendix A. A list of readings I have used in discussion with my classes and my lecture sequence will be available on my home page in the spring of 1997 (http://www.prenhall.com/bush). Information about the home page can be obtained from your local Prentice Hall representative.

I hope that the users of this book—both teachers and students—will find it to be a valuable tool. My publisher and I have made every effort to ensure that it is completely accurate and error-free. Should you find an error—or perhaps even a way to make the book better—I would be delighted to hear from you.

Acknowledgments

Writing a book represents a tremendous output of personal energy and, in my case, could only be achieved with the support of family, friends, and colleagues.

I owe a special debt of gratitude to my longtime friend, field companion, colleague, and mentor Paul Colinvaux. Without his example and inspiration I would never have tried to write a book. I wish to thank all those who have collaborated on past field projects, especially John Flenley and John Pethick, for the training they gave me as a graduate student. My later projects owe much of their success to Robert Whittaker and Tukurin Partomihardjo (expeditions to Krakatau, Indonesia), Paulo De Oliveira, Melanie Reidinger, Michael Miller, Miriam Steinitz-Kannan, Eduardo Asanza, Ana-Cristina Asanza-Sosa and Fausto Sarmiento (Amazonian and Andean studies), and Robert Rivera and George DeBusk (Central America). Many of my colleagues have provided valuable insights, and I particularly wish to thank James Clark, Richard Cook, Randy Kramer, Daniel Livingstone, Carol Mansfield, Dolores Piperno, Curtis Richardson, William Schlesinger, and Peter Thrall.

My publishing house has provided me with wonderful associates who have converted a pile of manuscript pages into a polished text. My special thanks go to my editors Sheri Snavely and Teresa Ryu for their steadfast belief in this project. Barbara Murray and Kimberly Karpovich have ensured that the project moved swiftly and smoothly to the production phase. The manuscript benefited greatly from the attentions of Margo Quinto, Heather Scott, and Sharon Anderson. To this whole group I extend a heartfelt thanks.

To Virginia, my love and thanks.

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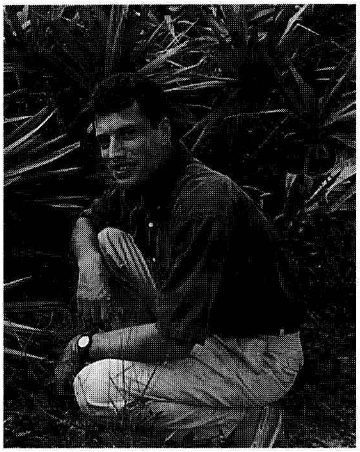

Mark B. Bush is an assistant professor of conservation biology at the Florida Institute of Technology. His B.S. and Ph.D. degrees were earned at the University of Hull in England. Between undergraduate and graduate school, Bush spent several years working for the British Trust for Conservation Volunteers as a specialist in conservation education. During this time, he designed and implemented the city of Hull's first inner-city nature area, a project that involved over 300 schoolchildren and adult volunteers. He used his garden as a tree nursery to provide more than 2000 native trees to be planted each year. Between 1985 and 1987, he also managed a small wetland nature reserve owned by the Yorkshire Wildlife Trust.

Professor Bush has spent more than 15 years in ecological research and has worked in some of the world's most remote locations. His field sites include Amazonia, Panama, Costa Rica, Ecuador, and the islands of Krakatau, Indonesia. He is an authority on the history of South and Central American tropical ecosystems and on island biogeography. He has lived in the United States since 1987, spending 4 years as a researcher at the Ohio State University, a year as a Mellon Fellow at the Smithsonian Tropical Research Institute in Panama, and 4 years teaching ecology and environmental science at Duke University.

Professor Bush is a member of Sigma Xi, the Society of Wetland Scientists, and numerous environmental organizations. His hobbies include scuba diving, kayaking, and hiking.

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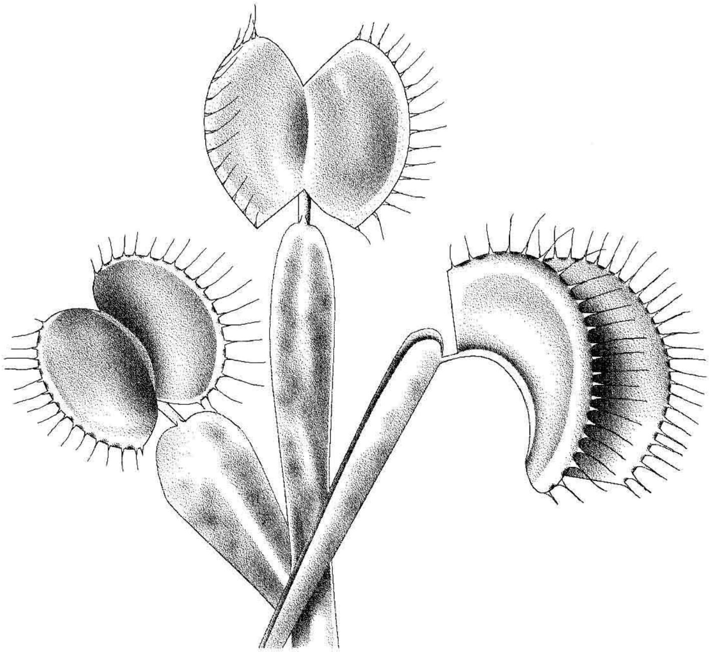
Diversity



1

Ecology, Environmentalism, and the First Polluters

- Developing and testing hypotheses
- Science and society
- Ecology is not environmentalism
- A brief history of Earth: The first billion years
- Trying to create life in a test tube
- Oceans and life
- The evolution of photosynthesis
- Oxygen producers pollute the planet

Ecology is the ideal science for the naturally curious. If you have ever wondered why leaves turn color before they fall from the tree, or why insects are small, or why there are two sexes of humans rather than three or four, you are pondering ecological questions. The term **ecology** comes from the Greek *oikos* meaning "house," in the sense of our environment. *Ecology* was first used as a scientific term in the late nineteenth century; it eventually came into popular use in the 1960s. Ecologists are scientists who study the distribution and abundance of species and their relationship to the environment, but more than that they always ask Why?

Developing and testing hypotheses

Good ecology, like all science, is investigative. Accurate observations are crucial to forming a clearly defined **hypothesis.** A hypothesis is an explanation of events or observations, and it usually accounts for all the available data on a subject. Above all, it must be testable. For it to be testable, the hypothesis must lead directly to a prediction, and it is the accuracy of the prediction that we can test. The testing may take the form of running an experiment in a laboratory, constructing a computer simulation, or spending long hours in the field observing, measuring, and quantifying. Data collection and analysis must avoid bias or preconceived ideas of what the result should be. Repetitions of the whole procedure must produce the same results for a hypothesis to be viable. The results of the analyses are then formulated into a logical scientific conclusion that is based on the results of the tests that confirmed the prediction. We can never prove a hypothesis; all we can do is disprove one. For example, an observation might be that all the swans that I have ever seen are white. I can then formulate the hypothesis that all swans are white. To test my hypothesis, I search throughout North America, perhaps finding another thousand white swans. I have added to my data set and strengthened my argument, but I have not proved the hypothesis. The search continues abroad; after traveling through Europe, Africa, and Asia, I have still seen only white swans; my hypothesis remains intact but unproved. I then go to Australia and find a black swan. This single new datum refutes my hypothesis. It does not matter how many white swans I find: A single black swan is enough to disprove the hypothesis. Science demands that I set up a new hypothesis to accommodate the new data. One hypothesis would be that all American swans are white. But this hypothesis is less useful than the original one because it contains the qualifier "American." Excluding a portion of the observed data weakens the hypothesis, especially when no factor is identified to justify or explain the exclusion. Furthermore, although the more limited hypothesis is testable, it does not lead the investigator into any new avenue of understanding. A better hypothesis—one that might lead to an improved understanding of the situation—would be that all white swans are more closely related to each other than a white swan is to a black swan. This prediction could be tested by comparing the genetic heritage of black and white swans.

As do all other disciplines of learning, ecology deals with a relative truth, not an absolute one. As we gain knowledge, our science and our hypotheses are continually being modified to take new information into account. Our scientific forebears founded their hypotheses on a contemporaneous understanding of what was true. Even if their argument had flawless logic, they would have reached faulty conclusions if their starting assumptions were false. Just because earlier workers did not always arrive at the right answer does not make them poor scientists. The faltering steps, or sometimes huge leaps, of these investigators sometimes advanced knowledge and sometimes took them down a blind alley. But even blind alleys and negative results form an important part of accumulated scientific knowledge. Later workers can use those results to help shape their hypotheses and arrive at a perception of nature.

Science and society

Because so many of our scientific discoveries have direct implications for future generations, the practice of science is tied intimately to the future of society. Scientific innovations have brought much good to our species. Science has helped us to feed the hungry and prevent disease, and it has given us heat and light in our homes. However, some scientific discoveries can be unpopular, even disturbing to our social fabric. For example, the sixteenth-century assertion of Copernicus that Earth revolved around the sun was a massive heresy in European Christianity. For centuries, it had been taught that the sun and all other heavenly bodies revolved around Earth. Orthodoxy placed man (I use man deliberately) at the center of the universe, and to relegate him to an out-of-the-way planet in a backwater of the Milky Way was sacrilege. This simple scientific postulate threatened the supremacy of the Catholic church, the infallibility of the Pope, and the structure of power in Renaissance Europe. In 1633, Galileo was able to verify many of the calculations of Copernicus through detailed observation of the movement of the stars using his own invention, the telescope. Galileo, the father of modern astronomy, was placed under house arrest for eight years because he "taught and held" Copernican views (the Vatican officially apologized for this injustice in 1979).

The technological improvements and discoveries of science continue to present society with mighty moral dilemmas. One such area of concern surrounds the morality of eugenics (the deliberate improvement of a species through manipulation of genes). The idea of altering the genetic code of an organism and thus improving a crop to produce a bigger yield, or a cow to produce more milk, has obvious appeal. A simple genetic operation that alters the configuration of a parent's chromosomes might mean the difference between the birth of a healthy child and one afflicted with Down's syndrome or epilepsy. These examples would seem to be laudable improvements. However, we have entered a moral, ethical, and even technological twilight zone. To what extent can we ethically and safely change the genes of an organism (and by extension, its evolution)? And who will decide? Is it right to alter chromosomes to prevent susceptibility to midlife breast cancer or the senility caused by Alzheimer's disease? Perhaps our genes could be manipulated to prevent dwarfism. But how tall should people be? The capacity for genetic engineering is growing rapidly, and a new moral code will be needed, as nothing exists to cover the contingencies that are emerging.

Another issue to be faced over the next few years will be euthanasia, sometimes known as the right to die. Battles have already begun over the legitimacy of living wills, the preapproval of a victim of disease or accident to have life support withdrawn, and the ethics of a doctor being involved in assisted suicide. The capacity of medicine to keep people "alive," despite failure of most of their natural functions, will increase. The malfunction of heart, lung, and kidney can all be offset by bedside machinery, and in the future perhaps the brain may be kept active through electrical stimulation. At what point should the machinery be turned off? And, again, who should decide?

Science and technology will also bring change to developing nations in the form of increased use of refrigerators, more cars, more air travel, new pesticides, and more food. Costs in energy, raw materials, and human labor must be paid for this development. Before long, we will be forced to reassess our use of natural resources. Conventional energy sources are finite, and eventually we will run short of coal, oil, and gas. The loss of these resources conjures powerful images of darkened cities in which artificial light is a luxury, cars are a distant memory, and industry has ground to a halt.

No one can deny that running out of manufactured energy would radically change society and that, unless something changes, it will happen eventually. Most environmental concerns may be less dramatic or less haunting, but they are no less real. Our development of the planet is causing natural resources and natural systems to become degraded. Some of these depletions, for example the loss of fertile soil, may cause natural systems to collapse long before we run out of coal. Pressing environmental problems include overpopulation, desertification, threatened and unclean water supplies (Figure 1.1), the destabilization of climate patterns, and the loss of potential medicinal chemicals as genetic biodiversity is reduced. Ecology cannot solve these problems. Solutions will require societal change, but ecology is the appropriate science to determine the extent of each problem and to suggest potential remedies. It is also the best science to point out the potential cost of ignoring evidence that we are changing our environment.

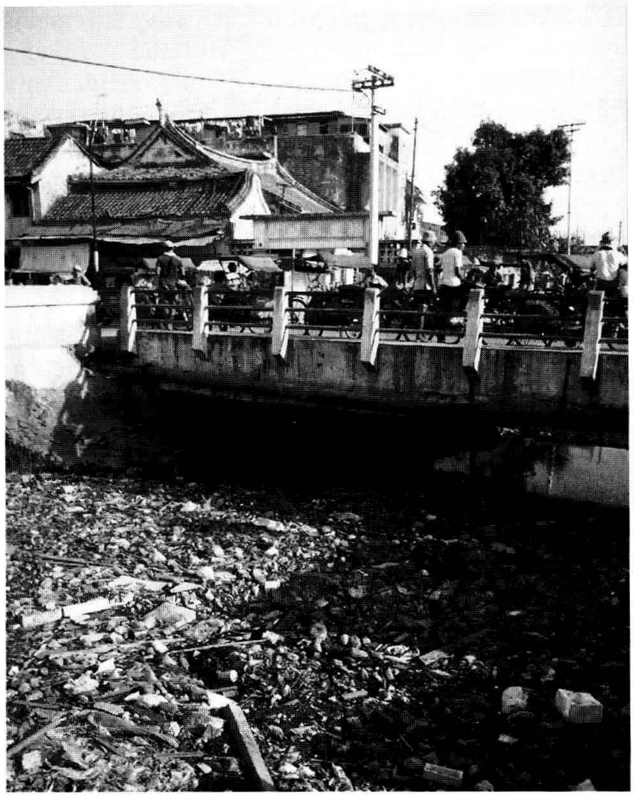


Figure 1.1 An open sewer in Jakarta, Indonesia. The water of the sewer is covered by trash, but the area beneath the bridge is kept clear as a bathing area. Water is drawn from this sewer for sale as drinking water. Unfit for drinking or bathing, but used for both, dirty water such as this is a major source of disease among the poor of less-developed countries.

In their quest to unravel and explain the workings of natural systems, ecologists have tended to devote most of their attention to pristine habitats that have been untouched by humans. It seems eminently reasonable to remove the messy influence of people—our pollution, our cutting and burning of forests, our hunting—to reach an understanding of the truly "natural" state. However, the more we find out about the history of almost any area, the more we find the influence of our forebearers. Hominids (members of the genus *Homo* and their immediate evolutionary ancestors), including the latest form, *Homo sapiens*, have been a feature of East African landscapes for more than 4 million years. Throughout that period, hominids have exerted a hunting pressure on animal populations. The entire ecology of North America may have been changed by the first humans to enter the land at the end of the last ice age, just 13,000 years ago. These hunters exterminated large mammals such as mammoths, ground sloths, and cave lions (Figure 1.2). Humans as hunters, fishers, and farmers have been shaping the landscape for millennia, and to exclude them from ecological studies as "unnatural" is highly artificial. Humans are part of nature. However, the consequences of human actions have been accelerating through time, as both our population and technological capacity increase. From an evolutionary perspective, the changes we effect are taking place at lightning speed. Evolution is the natural response of nature to change. Evolutionary processes cannot bring about change in natural populations of species fast enough to keep pace with human-induced changes in the environment.

In this book we will visit the areas of ecology needed to comprehend the environmental effects that modern humans are exerting on the landscape. With that foundation of knowledge, we can investigate the realities and fallacies of the environmental move-

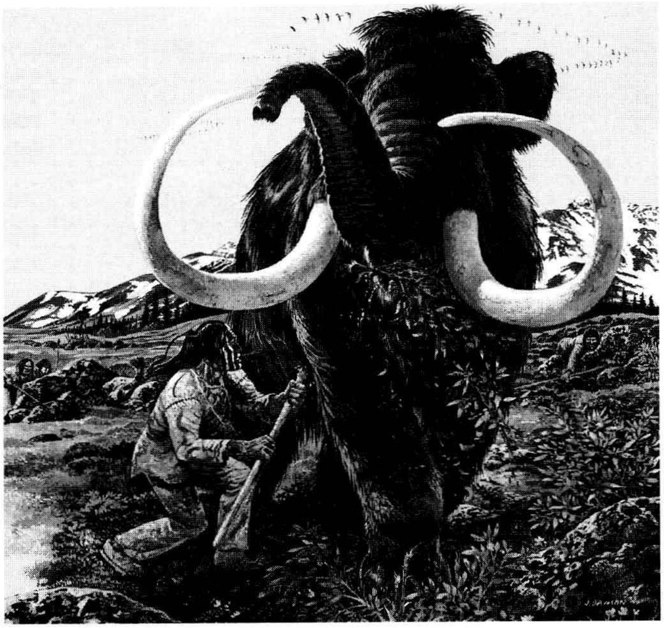


Figure 1.2 Extinct megafauna with human hunter.

ment and try to understand the underlying ecological cause of environmental problems.

Ecology is not environmentalism

Perhaps it is surprising to you that I am separating ecology from environmentalism. Despite their almost interchangeable use by the media and in common parlance, a true distinction does exist between them. Ecology is a science; environmentalism is a concern.

Tracing the roots of environmental concern is almost impossible. For as long as there have been humans, it is likely that someone was concerned over the changing state of the planet. In 1798, the English scientist Thomas Malthus expressed doubts about the ability of agriculture to feed a rapidly growing human population. In the early years of the twentieth century, John Muir (founder of the Sierra Club) worried that all of America would be covered by industry, urbanization, or agriculture. He crusaded to set aside and protect the California Sierra as a wilderness area and to secure a portion of the landscape where humans were secondary to nature. Muir succeeded in his quest and persuaded President Theodore Roosevelt to establish Yellowstone as the first national park in the United States.

The true environmental movement began in the 1960s, however, when environmental issues became part of the general public consciousness. In 1963, Rachel Carson published *Silent Spring*, a book that described the dangers of pesticides and the consequences of chemical pollution to our environment. Her message was stark and troubling: We are poisoning our planet. It was a message that changed how the public viewed agriculture, industry, and science. For the first time, the American public became concerned for the fate of their environment.

Environmentalists are people who believe that human actions are leading to the degradation of the planet and who object to this degradation on aesthetic, moral, and pragmatic grounds. Their arguments may be drawn on scientific data, but they are just as likely to be based on emotional appeal or on ethical or moral criteria. Both ecology and environmentalism have their place in modern society, but a distinction should be maintained. It is important that testable fact as determined by scientific investigation is kept discrete from heartfelt opinion or speculation.

The greatest value of the environmental movement is that it has increasingly sensitized our society to the relationship that exists between ourselves, nature, industry, and development. The danger of increased cancer rates from living close to nuclear waste sites or from the degradation of Earth's ozone shield is now common knowledge. The repeated message that pollution not only damages nature but also harms human health is now widely accepted. This message has been delivered through the environmental movement. Ecologists may reach the same