George W. Cox

Conservation Biology

second edition

concepts

and

applications

George W. Cox

Professor Emeritus - San Diego State University

Conservation Biology

second edition

concepts and applications

Boston Burr Ridge, IL Dubuque, IA Madison, WI New York San Francisco St. Louis
Bangkok Bogotá Caracas Lisbon London Madrid
Mexico City Milan New Delhi Seoul Singapore Sydney Taipei Toronto

McGraw-Hill Higher Education

A Division of The ***McGraw-Hill*** *Companies*

Project Team

Editor *Marge Kemp*
Developmental Editor *Kathy Loewenberg*
Production Editor *Kay J. Brimeyer*
Marketing Manager *Tom Lyon*
Designer *Kaye Farmer*
Art Editor *Jennifer L. Osmanski*
Photo Editor *Nicole Widmyer*
Advertising Coordinator *Heather Wagner*
Permissions Coordinator *Mavis M. Oeth*

President and Chief Executive Officer *Beverly Kolz*
Vice President, Director of Editorial *Kevin Kane*
Vice President, Sales and Market Expansion *Virginia S. Moffat*
Vice President, Director of Production *Colleen A. Yonda*
Director of Marketing *Craig S. Marty*
National Sales Manager *Douglas J. DiNardo*
Executive Editor *Michael D. Lange*
Advertising Manager *Janelle Keeffer*
Production Editorial Manager *Renée Menne*
Publishing Services Manager *Karen J. Slaght*
Royalty/Permissions Manager *Connie Allendorf*

Cover credit © Siegfried Eigstler/Tony Stone Images

Chapter opening photos for chapters 1–5, 9–12, 15, 26, 28–30 by G.W. Cox;
6, 7: U.S. Foresty Service; 8: © Doug Sherman; 13: © Richard O. Bierregaard, Jr.;
14, 16–19, 22, 24, 25: Digital Stock and Corel CD's.

The credits section for this book begins on page 351 and
is considered an extension of the copyright page.

Library of Congress Catalog Card Number: 96–60380

ISBN 0–697–21814–7

Printed in the United States of America.
2460 Kerper Boulevard, Dubuque, IA 52001

10 9 8 7 6 5

Conservation Biology

To Darla

for helping in field studies throughout the world,
and for patience, encouragement and love during
the preparations of this textbook

preface

The Earth is now in a critical period for the survival of its natural ecosystems and their plant and animal members. The continuing growth of human populations, through consumption of resources and discharge of the resulting wastes, is modifying ecosystem processes on a global scale. Global warming, stratospheric ozone depletion, acid deposition, tropical deforestation, desertification, accelerating soil erosion, chemical pollution—these and other large-scale threats are combining to threaten a massive loss of biodiversity. Yet our ultimate well-being depends on health of the global processes that are experiencing these massive changes—the myriad interactions among plants, animals, microorganisms, and their abiotic surroundings that provide us with food, fiber, medicine, pure water, and clean air. The crisis of survival of natural ecosystems and their members is a crisis of survival of the human species.

This global challenge requires our personal involvement. As responsible citizens, we must educate ourselves about the nature of this crisis, and about the choices that must be made in meeting it. An understanding of basic ecology has become a requirement of every educated person.

Each of us is now faced with decisions, on an almost daily basis, about environmental issues relating to the global ecosystem. Should we buy only tuna that were caught by dolphin-safe techniques, eat hamburgers made from beef that was not produced on tropical pastures created by deforestation, or use paper products instead of plastic and styrofoam items that might pollute the oceans? Should we support preservation of old-growth forests in the Pacific Northwest, taxation of sugar to aid the restoration of the Florida Everglades, and removal of exotic species from national and state parks—even the removal of mountain goats from Olympic National Park? Should we oppose efforts to weaken the Endangered Species Act and the Clean Water Act, to reduce populations of wolves and grizzly bears in Alaska in efforts to increase moose and caribou populations for hunters, or to divert more water from the Platte River so that greatly reduced flow reaches the portion of the river in Nebraska where migratory cranes stop in the spring? Should we support measures to reduce power plant emissions that contribute to acid rain, to ban the use of chlorofluorocarbons and other chemicals that damage the stratospheric ozone layer, and to reduce the use of fossil fuels that contribute to the greenhouse effect and global warming? Should we continue to require shrimp fishermen to use devices that prevent sea turtles from entering their nets, to protect the mountain lion from hunting in California, or to support an international ban on trade in elephant ivory? These, and countless issues like them, demand the collective decision of society.

The goal of this text is to introduce the reader to the nature of biodiversity in its broadest sense, to the threats to its survival that are intensifying daily, and to ecologically sound approaches to conserving biodiversity. The earth's biodiversity is not only the remarkable product of billions of years of evolution. It is our survival system.

Conservation Biology: Concepts and Applications is based on the course "Conservation of Wildlife" that I have taught at San Diego State University since the early 1960s. Its content has evolved considerably over the years, although remaining concentrated on the global ecosystem and its health. This same course was the stimulus for *Readings in Conservation Ecology,* first published in 1969 by Appleton-Century-Crofts. The students in this course (in some cases now the offspring of earlier students!) thus deserve credit for helping to maintain their instructor's interest in conservation ecology, especially over a long period when conservation was placed on the back burner by society at large. My sincere appreciation goes to all those students.

New to This Edition

The first edition of this text, titled *CONSERVATION ECOLOGY: BIOSPHERE AND BIOSURVIVAL,* emphasized the ecosystem concept and its application to conservation issues. This second edition has broadened in coverage, and includes several new chapters. Two topics of growing scientific concern have received full chapter treatment: habitat fragmentation and global climate change. The examination of societal issues has also been broadened and strengthened by inclusion of a chapter on environmental ethics and by the expansion of other chapters to include discussions of public policy relating to conservation of biodiversity and of efforts to achieve sustainability in the relation of human life within the biosphere. A chapter dealing cohesively with ecological principles relevant

to conservation of biodiversity has been placed early in the text, and the nature and origin of biodiversity have received expanded coverage. Because of these changes, I have retitled the text *CONSERVATION BIOLOGY: CONCEPTS AND APPLICATIONS*. Its coverage retains an essential emphasis on ecological aspects of conservation science, but now gives fuller coverage to fields with which ecology interfaces, including biological fields such as systematics and genetics, as well as rapidly growing interdisciplines such as ecological economics and environmental ethics. Thus, this text represents a comprehensive examination of the discipline now generally known as *Conservation Biology*.

Acknowledgments

I thank the many colleagues, including several former students, who have reviewed chapters or groups of chapters: Edith B. Allen, Ellen T. Bauder, A. T. Bergerud, Lawrence J. Blus, Mark S. Boyce, Beth Braker, Richard W. Braithwaite, Bayard Brattstrom, John Celecia, Charles F. Cooper, Deborah M. Dexter, Thomas A. Ebert, David A. Farris, Christopher G. Gakahu, Renatte K. Hageman, Rick A. Hopkins, Don Hunsaker II, Jodee Hunt, Stuart H. Hurlbert, Joseph R. Jehl Jr., David W. Johnston, Steve Kingswood, Barbara E. Kus, Michael Kutilek, Stephen Leatherwood, Leroy R. McClenaghan, Dale R. McCullough, Pierre Mineau, Dieter Muller-Dombois, David A. Munro, Harry M. Ohlendorf, Dwain Parrack, William F. Perrin, Louis F. Pitelka, Donald B. Porcella, Philip R. Pryde, Keith Ronald, Victor B. Scheffer, J. Michael Scott, Robert C. Stebbins, Douglas H. Strong, William Toone, Ross A. Virginia, David Western, Kathy S. Williams, Susan L. Williams, Joy B. Zedler, and Paul H. Zedler.

In addition, I thank the individuals who helped me obtain illustrations for the text. These include Anthony F. Amos, Spencer Beebe, Charles Birkeland, Richard O. Birregaard Jr., Richard W. Braithwaite, James J. Brett, David S. Brookshire, Lincoln Brower, Wendy M. Brown, Graeme Chapman, Walter Courtenay, A. T. Cringan, Don Despain, Deborah Dexter, John Francis, Donald W. Kaufman, Joseph R. Jehl Jr., Peter Johnson, Janet Jorgenson, Charles D. Keeling, Stephen Leatherwood, Thomas E. Lovejoy, A. W. Maki, Peter Meserve, Robert Mesta, J. P. Myers, David A. Norton, Bruce Nyden, Storrs Olson, David R. Parsons, Donald B. Porcella, Rolf O. Peterson, Dan Reed, Scott Robinson, John D. Schroer, W. Roy Siegfried, Robert L. Smith, Tom Stehn, Brent Stewart, Harrison B. Tordoff, H. W. Vogelmann, LaRue Wells, Dorn Whitmore, Susan Williams, Thomas D. Williams, and David Zoutendyk.

I would especially like to thank the hard-working editorial and production staff at Wm. C. Brown publishers—particularly Marge Kemp, Kathy Loewenberg, Kaye Farmer, Kay J. Brimeyer, Mavis Oeth, Nicole Widmyer, and Jennifer Osmanski.

George W. Cox

brief contents

contents

part

one

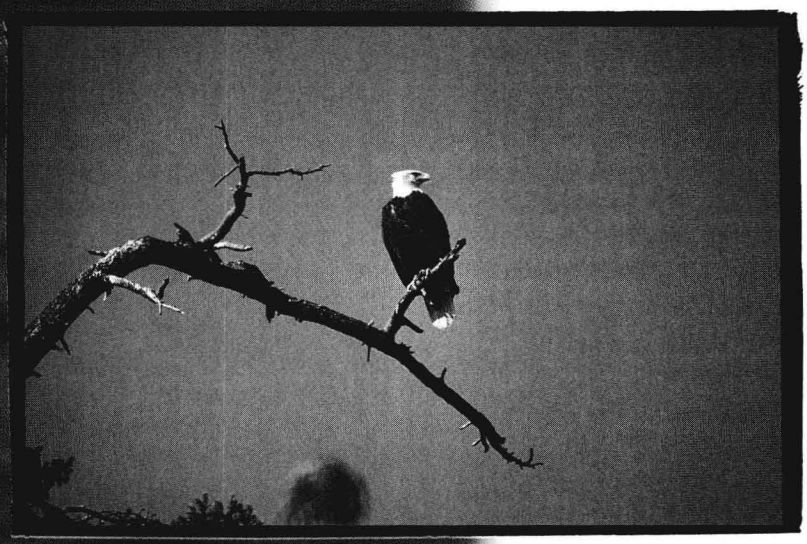
Basic Concepts

Conservation biology is a new science that has drawn together scientists and environmentalists in basic and applied studies of biodiversity. This introductory section examines the nature of this emerging field, and traces the history of conservation activism in North America. Following this, we survey basic principles of ecology, with emphasis on the concept of the ecosystem and its central role in conservation management. Finally, we examine biodiversity in detail and consider the processes of extinction that are leading to a biodiversity crisis.

chapter

1

Conservation Biology: Emergence of a Discipline



Outline

Throughout history, times of crisis often have been times of advance in human capabilities. In Western history, crises have fostered advances in science and technology. Crises also have stimulated the formation of new institutions, both governmental and private. In the 1990s, conservation biology has emerged as a vital new branch of science directed at an environmental crisis: the human population stands on the verge of causing the massive extinction of species and loss of ecosystems throughout the biosphere. What is this newly organized branch of science? Can it contribute to the formulation of policies for protection of the earth's biotic heritage and the management of ecological resources such as forests, rangelands, fisheries, and game animals?

Conservation biology is the scientific study of biodiversity and its management for sustainable human welfare. It seeks to understand how the rich variety of plant and animal life around us arose, how it has been maintained by natural processes, and how we can utilize this resource sustainably. It is not content with understanding the patterns of biodiversity and their origin; systematics and evolutionary biology effectively fill this niche. Nor is it concerned only with encouraging the protection of biodiversity: this niche is filled by a variety of activist conservation organizations. Conservation biology is unique in focusing on the interaction of humans with biodiversity, seeking to reveal the aspects of this interaction that are significant to human interests, and striving to answer questions about how these aspects can be managed for sustainable human benefit.

But a crisis does exist, and some authors have contended that conservation biology has the primary role of preventing the loss of biodiversity. Soulé (1985) states that the mission of conservation biology is . . . to provide principles and tools for preserving biological diversity, and Primack (1993) describes it as . . . the new, multidisciplinary science that has developed to deal with the crisis confronting biological diversity. Brussard (1995) recently has affirmed that conservation biology has the specific goal of preserving biodiversity.

In this chapter we shall first describe the relation of conservation biology to the fields of science, humanities, and human affairs with which it interfaces. Next, we shall examine the biodiversity crisis and consider how this crisis has given rise to the conservation biology movement. Finally, we shall define the goals of conservation biology in the study and management of biodiversity.

Conservation Biology is the science of survival for thousands of species, including the American bald eagle.

Fields with which Conservation Biology Interfaces

Conservation biology is engaged in activities that involve the diverse, often conflicting, interests of complex human society. Thus, it must draw knowledge and use methods not only from biology, but also from the physical sciences, engineering, economics, sociology, law, history, and political science. Conservation biology has both basic and applied aspects as well. In the area of basic science, our knowledge of how both natural and human-dominated ecosystems function is still primitive. Thus, a major goal of conservation biology must be to examine these systems in detail and reveal the ways in which biodiversity is important to their function. Ultimately, this knowledge will be of great value to humanity. As an applied science, however, conservation biology functions to obtain data and devise methods to manage ecological systems to achieve goals that society has defined. Through the political process, for example, society may decide that national parks should be managed to minimize the risk of disastrous fires, that pollution of streams and lakes be reduced, that productivity of game or fish populations increase, or that extinction of species be prevented. Conservation biologists then must use their knowledge of ecological processes to develop management procedures to obtain the desired goal.

From the start, conservation biology has emphasized an interdisciplinary approach that draws on many basic and applied disciplines within biology (Brussard 1991) (Fig. 1.1). Perhaps the closest relationships are with ecology, the science concerned with relationships of organisms with each other and with their nonliving environment. Some branches of ecology deal with particular groups of organisms; these include plant ecology, animal ecology, and microbial ecology. Others, such as terrestrial ecology, freshwater ecology, and marine ecology, focus on particular environments. Still others, such as organismal, population, community, and ecosystem ecology, are concerned with different levels of organization. Other fields of biology, however, are essential to conservation biology. Captive breeding and reintroduction of animals, for example, require the expertise of ecologists, endocrine physiologists, geneticists, animal behaviorists, wildlife managers, veterinarians, and biopark managers. Conservation biology thus is drawing together scientists from many subfields of biology that have grown apart over the past century.

Moreover, to achieve a defined goal such as the protection and recovery of an endangered species, conservation biologists must work in an even broader, real-world context of societal institutions and laws. They must understand the biology of the species, the ways in which human activities are likely to affect its environment, and how efforts to preserve the species can be carried out under the constraints of laws, available funds, and public opinion. Like a doctor of medicine, a successful conservation biologist must be able to integrate the areas of research, diagnosis, and treatment. The global crises that humanity now confronts, in fact, reflect the lack of effective integration of scientific research, monitoring of environmental change, and corrective management.

Conservation biology thus interacts with many nonbiological fields of the physical sciences, social sciences, and humanities

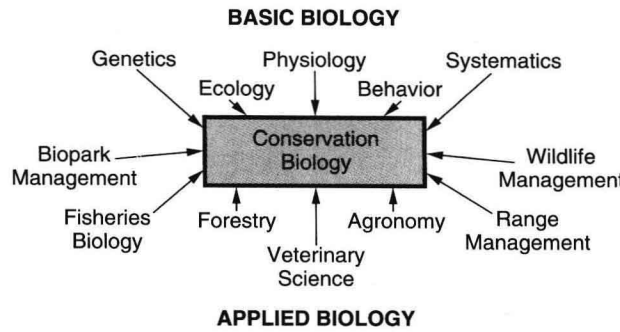


FIGURE 1.1

Conservation biology has close ties to many basic and applied disciplines within biology.

(Fig. 1.2). These fields are as important to sound environmental management as is the core science of conservation biology. An individual conservation project may require collaboration of individuals with expertise in many of these areas. Ecosystem restoration efforts, for example, may require active participation of individuals skilled in biopreserve design, ecological systems modeling, ecological economics, and environmental law, as well as advice from scientists and engineers in plant ecology, agronomy, hydrology, geology, and civil engineering.

An interface field of particular interest is that with the humanities. This is the arena in which society debates the merits of alternative values: environmental ethics, or in its more popular form, environmentalism. **Environmental ethics** examines moral values relating to the natural environment. Leopold (1949), in his essay on the land ethic, stimulated modern interest in environmental ethics when he recommended,

> A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise.

Leopold's writings have become a powerful catalyst for the field of environmental ethics, now one of the most active interfaces of science and the humanities (Schrader-Frechette 1981; Rolston 1988).

Environmentalism is the popular expression of environmental ethics. It is a societal movement, in the words of Scheffer (1991),

> . . . toward understanding humankind's natural bases of support while continuously applying what is learned toward perpetuating those bases.

In other words, environmentalism is the effort to live in harmony within the global ecosystem. Environmentalism is thus a philosophical conviction that the future of humankind depends on the establishment of a sound relationship between humans and the natural world. This conviction provides the political support for many efforts of conservation biology. Many, if not most, conservation biologists are environmentalists at heart, although to do their job right, they must also be objective scientists. Since environmental policy is the responsibility of all of society, environmental ethics and environmentalism are important