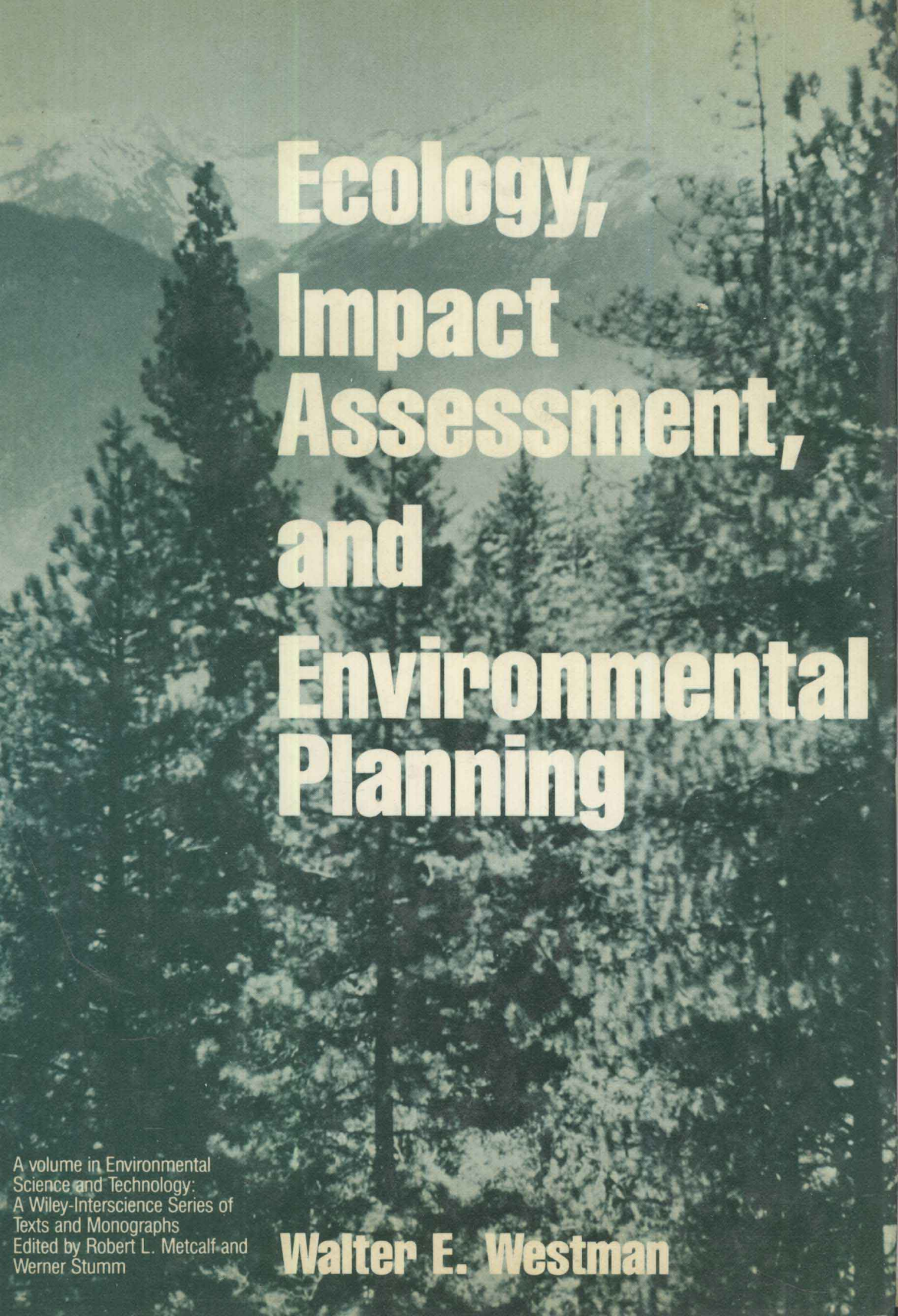

Ecology, Impact Assessment, and Environmental Planning

A volume in Environmental Science and Technology: A Wiley-Interscience Series of Texts and Monographs Edited by Robert L. Metcalf and Werner Stumm

Walter E. Westman

ECOLOGY, IMPACT ASSESSMENT, AND ENVIRONMENTAL PLANNING

WALTER E. WESTMAN

University of California, Los Angeles

A Wiley-Interscience Publication

JOHN WILEY & SONS

New York Chichester Brisbane Toronto Singapore

Library of Congress Cataloging in Publication Data:

Westman, Walter E., 1945–
Ecology, impact assessment, and environmental planning.
(Environmental science and technology, ISSN 0194-0287)

"A Wiley-Interscience publication."
Includes bibliographical references and index.
1. Ecology. 2. Environmental impact analysis. 3. Land use—Planning. I. Title. II. Series.

QH541.W43 1984 333.7 84-11867
ISBN 0-471-89621-7
ISBN 0-471-80895-4 (pbk.)

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

FOREWORD

Walter Westman brings an extraordinary range of interest and experience to bear on the awkward, almost impossible problem of measuring the value of resources and predicting changes due to disturbance. Economic gradients seem all-powerful in determining details of management of forests, fisheries, air, water, and land. Emphasis on immediate profits generates overwhelming pressures to discount the future at virtually any cost. How can we see that appropriate values are assigned to clean water, clean air, and the biotic systems of land and sea that maintain a stable biosphere?

The first step is measurement. What are the dimensions of the renewable resources of the earth? What tools do we have, how accurately can the measurements be made, what are the values gained and lost through management? And what units are best understood by those who join in such important decisions?

Westman addresses these and related issues from the standpoint of a biologist experienced in ecology. But he is also experienced in law, in government, in politics, in economics, in geography, and planning. About these subjects, all obviously close to his heart, he has written fully and well.

We need this book. We need it for the synthesis it brings to the challenge of measuring and interpreting the values of resources that are so commonly discounted or ignored. We need it to enable anticipation of effects of intensified human activity. We need it too for the discussion and argument it will engender, for the stimulation of analysis and the potential that it shows for development of still better methods. The book will be vital to anyone interested in developing his or her own objective appraisal of the limits of the earth for support of humankind.

Woods Hole, Massachusetts
July 1984

G. M. Woodwell
Director, The Ecosystems Center
Marine Biological Laboratory

SERIES PREFACE

Environmental Science and Technology

The Environmental Science and Technology Series of Monographs, Textbooks, and Advances is devoted to the study of the quality of the environment and to the technology of its conservation. Environmental science therefore relates to the chemical, physical, and biological changes in the environment through contamination or modification, to the physical nature and biological behavior of air, water, soil, food, and waste as they are affected by agricultural, industrial, and social activities, and to the application of science and technology to the control and improvement of environmental quality.

The deterioration of environmental quality, which began when people first collected into villages and utilized fire, has existed as a serious problem under the ever-increasing impacts of exponentially increasing population and of industrializing society. Environmental contamination of air, water, soil and food has become a threat to the continued existence of many plant and animal communities of the ecosystem and may ultimately threaten the very survival of the human race.

It seems clear that if we are to preserve for future generations some semblance of the biological order of the world of the past and hope to improve on the deteriorating standards of urban public health, environmental science and technology must quickly come to play a dominant role in designing our social and industrial structure for tomorrow. Scientifically rigorous criteria of environmental quality must be developed. Based in part on these criteria, realistic standards must be established, and our technological progress must be tailored to meet them. It is obvious that civilization will continue to require increasing amounts of fuel, transportation, industrial chemicals, fertilizers, pesticides, and countless other products and that it will continue to produce waste products of all descriptions. What is urgently needed is a total systems approach to modern civilization through which the pooled talents of scientists and engineers, in cooperation with social scientists and the medical profession, can be focused on the development of order and equilibrium in the presently disparate segments of the human environ-

ment. Most of the skills and tools that are needed are already in existence. We surely have a right to hope that a technology that has created such manifold environmental problems is also capable of solving them. It is our hope that this Series in Environmental Sciences and Technology will not only serve to make this challenge more explicit to established professionals but that it also will help to stimulate students to pursue career opportunities in this vital area.

Robert L. Metcalf
Werner Stumm

PREFACE

Elucidating the interrelations between the environment and human activities is a central goal of much research in both the natural and social sciences. Yet the task of *predicting* the impact of human actions on ecosystems is in many ways a nascent field, replete with challenges to the student and professional. I discuss here some concepts and methods for assessing the effects of human activities on natural ecosystems. By the "assessment" process I refer to the collection and analysis of data, the prediction of effects, and the evaluation of the human significance of the results. I also discuss the legal and planning context within which assessment takes place. I have written to introduce readers to issues and literature in this complex field.

I have aimed to draw together the perspectives of three subdisciplines which have evolved within distinct traditions: applied ecology, environmental planning, and ecological impact assessment. The approaches used to prepare environmental impact statements are subsumed within this larger context. My focus is on biological and physical, rather than socioeconomic, components of environmental systems.

By drawing from the research literature, I have given this book a deliberate theoretical focus. The last five chapters constitute a review of modern concepts in applied ecology of relevance to environmental planning and analysis and provide an extensive biological core for the book. The earlier chapters, which deal with topics in environmental planning and impact assessment, are written from an ecological perspective.

In addition to reviewing commonly used methods of assessment, I also describe some that are newborn and teething. While some techniques will be of aid to those involved in rapid survey tasks, other techniques are appropriate only for longer-term studies. Most of the approaches have been selected to highlight important conceptual issues in a rapidly evolving field.

I stress the interdisciplinary nature of the assessment task, drawing on perspectives offered by planning, law, decision theory, economics, physical geography, ecology, toxicology, and other fields. The broader social science context (law and planning, evaluation and decision making) is discussed in the first five chapters, followed by predominantly natural science approaches to the prediction of impacts to ecosystem components—land, air, water (Chapters 6,7), and biota (Chapters 8–12). Quantitative approaches and probabilistic ways of thinking are emphasized, and applications of the computer are noted throughout.

G. Evelyn Hutchinson has written (1975, p. vii), "The ecologist is continually having to look at aspects of nature with which he is unfamiliar and perforce must be an amateur for much of his working time."* This experience is shared by environmental analysts of all stripes. Because of the nature of environmental assessment, the range of topics in this book is unabashedly large. My aim has been to present a spectrum of concepts and methods to illustrate both the reach of the subject area and its commonalities. Although I have stressed the conceptual basis for the topics addressed, and used numerous examples, discussion of many issues is condensed. Citations to approximately 1200 recent books and articles provide a source for readers seeking more detailed treatment of a topic.

The book is appropriate as a text in an upper division undergraduate, graduate, or professional course in impact assessment, applied ecology, environmental planning, resource management, or environmental design. The book should also be useful as a reference for environmental consultants, resource managers, planners, and decision makers. Some background in the environmental sciences is assumed, including an elementary knowledge of ecology, economics, and statistics.

I write from the perspective of an academic with primarily ecological training. I have worked in the legislative branch of government and in university teaching and research in departments of botany, urban planning, and geography, primarily in the United States and Australia. I have sought to broaden the viewpoint of this book by surveying techniques used in professional and academic circles worldwide and have written for an international audience. Nevertheless, the United States serves as the most frequent point of reference.

I wish to thank the Department of Forestry and Resource Management at the University of California, Berkeley, for hosting me during a sabbatical leave when much of this book was written, and students and colleagues at the Department of Geography, University of California, Los Angeles, for their support. I am also grateful to Dr. George M. Woodwell, Director of the Ecosystems Center, Marine Biological Laboratory, Woods Hole, for writing the Foreword, and to the following people for their numerous helpful comments on the outline and drafts of particular chapters: S. Beatty (UCLA), J. Cairns, Jr. and D. Conn (Virginia Polytechnic Institute and State University), R. Corwin (Marin County Planning Department), J. T. Gray (Dames and Moore), E. Hobbs (Colgate University), D. Liverman (University of Wisconsin), T. Meredith (McGill University), C. Salter (UCLA), and G. Wandesforde-Smith (University of California, Davis).

WALTER E. WESTMAN

Los Angeles, California
July 1984

* Hutchinson, G. E. (1975). *A Treatise on Limnology*. Vol. 3. Wiley-Interscience, New York.

CONTENTS

PART III. SUMMARIZING AND EVALUATING IMPACTS

PART IV. PREDICTING IMPACTS: THE PHYSICAL ENVIRONMENT

PART V. PREDICTING IMPACTS: THE BIOTA

PART ONE

INTRODUCTION

1

ECOLOGICAL IMPACT ASSESSMENT AS A DISCIPLINE

The demand for impact analysis has propelled ecologists, geographers, and planners into what has at times seemed a murky world of futurology. Imprecision in predicting the response of ecosystems to human activities has stemmed from at least two sources: the difficulty of extending a largely descriptive ecological literature into a predictive mode, and the complexity and interconnectedness of ecosystems themselves. Yet within the recent literature in a range of disciplines lie concepts and methods that provide the framework for a quantitative science of ecological impact analysis.

Ecological impact assessment involves not only analysis but also evaluation of the significance of the predicted ecological alterations to human society. The evaluation process contains its own imprecisions in striving to apply human values in an explicit, quantitative fashion. In this book the broad themes of ecological impact analysis and evaluation are reviewed.

The prediction of impacts may form part of tasks in environmental planning and design, resource management, and applied ecology. To design an urban development project, a park reserve, a rehabilitation scheme, or a forest management plan requires understanding how the natural environment will respond to the proposed manipulation. This calls upon a knowledge of ecology, principles of environmental design, and a predictive capability. New policies, laws, or technological innovations may also be evaluated using principles of impact assessment.

There is not yet a universally acknowledged body of theory and methodology that can be applied to the analysis and evaluation of future impacts on the natural environment. Most impact analysts began their task by drawing on concepts and methods in a range of traditional disciplines, and the practice of impact assessment remains interdisciplinary. Nevertheless, new approaches of particular application to ecological impact assessment have developed, new scholarly journals—such as *Environmental Impact Assessment Review*, *Environmental Management*, and the *Journal of Environmental Management*—have appeared, and learned societies—such as

the International Association for Impact Assessment and the Association of Environmental Professionals—have formed.

ECOLOGICAL IMPACT ASSESSMENT DEFINED

This book focuses on the prediction and evaluation of the effects of human activities on the structure and function of "natural" ecosystems—those close to their evolutionary state—though many of the concepts and methods also apply to heavily modified systems such as farms or urban areas (Figure 1.1). The realm of concern is not only the tangible features or "structure" of ecosystems (e.g., plants, animals, soil) but also the exchange of energy and materials between ecosystem components: the dynamics of interaction or "function" of ecosystems.

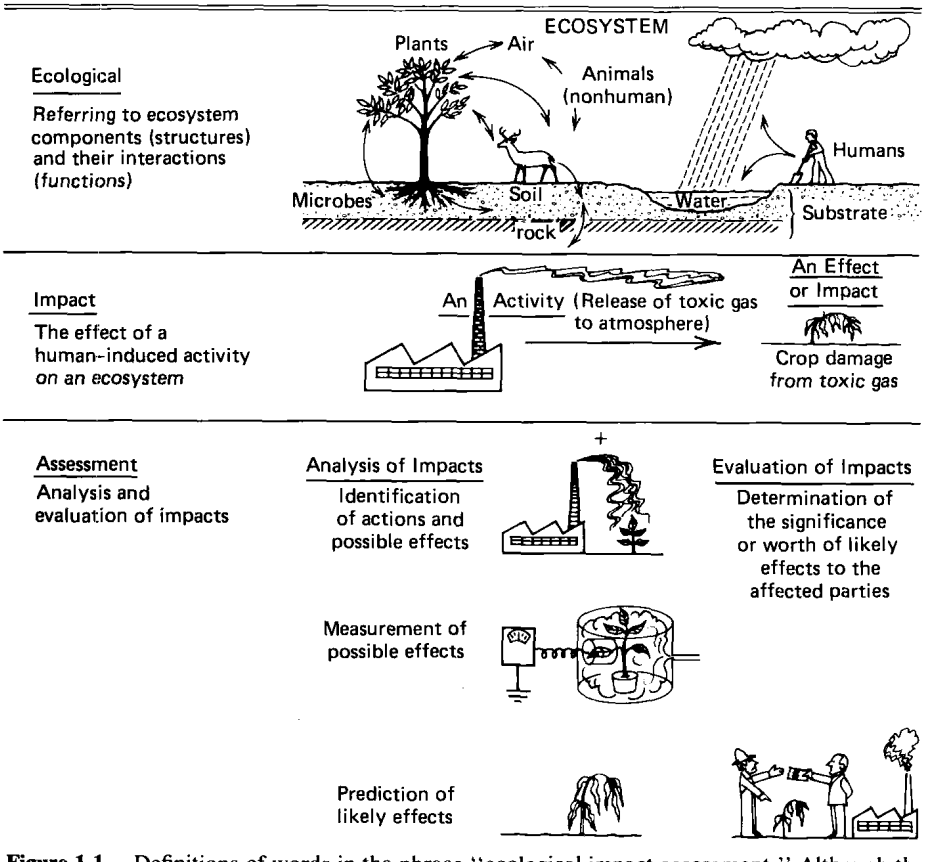

Figure 1.1. Definitions of words in the phrase "ecological impact assessment." Although the phrase is often associated with environmental impact statements, it can also refer to a wide range of predictive tasks within environmental planning.

A number of authors (Andrews et al. 1977, Dooley 1979, Lee 1982) have noted that the term "impact" has sometimes referred both to a human-induced *action*, or activity, and to its *effect* on ecosystems, or to the *effect* and its *significance* to human society. Action, effect, and significance are three distinct concepts in impact assessment; we will limit the term impact to the *effect* of a human-induced action on an ecosystem.

"Assessment" here refers to *analyzing* and *evaluating* impacts on ecosystems. *Analysis* is the *objective* task of identifying actions, taking measurements of baseline conditions, and predicting the changes to these baseline conditions that are likely to occur as a result of the actions. *Evaluation* is a *subjective* or normative task which depends on the application of human values. It involves determining the significance of the effects to the affected parties. In the case of effects on objects rather than people, the owners of those objects generally are taken to represent them.

For example, to evaluate the effect of air pollution damage to a crop, one would determine the significance of the damage to the farmer who owned the crop. Often the significance is measured in economic terms, such as the market value of the amount of the crop that was lost. Many objects in ecosystems are not marketed (e.g., mosquitoes), and damage to these objects must be evaluated in other ways. In the case of air pollution damage to a mosquito, the owner of the marshland on which it was killed may actually feel blessed by this event, in which case the significance of the damage may be evaluated as beneficial, though no monetary value may be placed on the benefit. A devout Jain or Zen Buddhist, who sanctifies all creatures including insects, would be less pleased (Watanabe 1974). Clearly the value placed on the significance of an effect depends on whose values are employed.

RATIONALES FOR ASSESSING ECOLOGICAL IMPACTS

The opportunity to identify costly and undesirable effects, and to modify projects in the design stage, is a chief rationale for conducting environmental impact assessments. In the United States as of 1970, and in at least 29 other countries since, an environmental impact statement (EIS) or report has been required for selected actions that are expected to have significant effects on the human environment. The cost of preparing such assessments at the federal and state level in the United States averages 1% or less (range: 0.1–5.4%) of the total cost of the proposed projects (Council on Environmental Quality 1976; Zigman 1978). Design modifications sometimes themselves lead to cost savings: design changes due to EIS's saved $35 million in construction costs for 49 sewage treatment plants in the United States.

The costs of ignoring potential ecological effects of human activities are well illustrated by the discharge of kepone pesticide into the James River of Virginia, a tributary of Chesapeake Bay. Kepone was discharged directly to the sewage treatment plant in Hopewell, Virginia, from the kepone manufac-

turing plant during 1966–1975, saving the manufacturer approximately $200,000 in pollution control costs (Miller 1982). Kepone killed sewage-digesting microorganisms, resulting in the discharge of inadequately treated sewage, and kepone, into the James River. A 150 km stretch of river was closed to fishing indefinitely (Council on Environmental Quality 1979), with sport and commercial fishery losses estimated at $20 million during 1975–1980 (Council on Environmental Quality 1980). The company has so far paid $13 million of the $160 million in health damage suits from workers and an additional $13 million in pollution fines. Two company executives were also convicted and fined (Council on Environmental Quality 1977).

Although economic indexes provide a means to quantify some social gains and losses, many impacts on social structures and natural resources cannot be adequately expressed by economic values. The realm of impact assessment embraces a larger set of changes in features of the human environment than those expressed by economic indexes. This book reviews a range of approaches for expressing and evaluating impacts quantitatively.

INTEGRATED IMPACT ASSESSMENT

A human action such as mining simultaneously affects both the natural and the social environment, not only displacing plants and polluting water but creating jobs and relocating people. Clearly a comprehensive assessment of mining impacts would have to consider both ecological and social effects, and the higher-order cumulative effects that result from their interaction.

In the early 1970s, when environmental impact statements were first being written in the United States as a result of the National Environmental Policy Act (1969), most EISs were limited to the webwork of effects on the natural environment. Through a series of legal challenges and administrative modifications, the scope of impact statements was gradually broadened to encompass a range of social and economic concerns (Figure 1.2, Table 1.1). Social impact assessment in the United States was also stimulated by the requirements of Sec. 122 of the River and Harbor and Flood Control Act of 1970 (U.S. Army Corps of Engineers 1973) and the requirement of the Department of Housing and Urban Development to prepare impact assessments for urban development plans.

Examination of the full social and ecological impacts of a proposed action requires a "holistic" approach, in the sense that examination of the effects on natural and social systems separately will not reveal the full scope of interactive effects. An example in which the secondary interactions between social and ecological effects played the crucial role in deciding the fate of a project occurred in the case of a proposed airport north of Everglades National Park, a major subtropical swamp forest area in Florida. The EIS indicated that the direct ecological effects of constructing and operating the