Biological Monitoring for Environmental Effects

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Foreword

Biological monitoring for environmental effects is an old concept that has been used by biologists for years. This technical area of biology has, however, only recently been given the emphasis that it deserves. Unlike physical-chemical monitoring methods that require sophisticated instrumentation, computers, and analytical techniques necessitating heavy capital investments, biological monitoring has been given only modest support. Consequently, its potential role in monitoring biological effects has been slowly recognized.

The research findings and recommendations made by the scientists and engineers who participated at this conference/workshop should dispel any doubts about the need to monitor our environment. Biological monitoring is a valuable tool in seeking to understand both reversible and potentially irreversible environmental effects. For responsible authorities in government and private industry not to recognize this would be a serious mistake.

I am hopeful that this book will have an impact upon the future planning of environmental-monitoring programs in the United States and other countries. I also hope it will provide useful guidance in developing programs to evaluate man's impact on his limited natural resources.

Arthur W. Cooper
Head, Forestry Department, N.C.S.U.
President, Ecological Society of America

Preface and Acknowledgments

This book is a result of a conference and workshop that served as a forum for those involved in research, monitoring, legislative development, and the regulatory aspects of biological monitoring of environmental quality. Federal, state, academic, and industrial scientists have exchanged thoughts and formulated recommendations on technical and policy issues in this rapidly growing field.

There is a continuing need to identify the utility of a wide array of bioindicators and biological monitoring techniques for determining both the short- and long-term effects and trends of human activities on our ecosystem and the quality of our environment.

Biological monitoring and physical-chemical monitoring of our environment are at times regarded as separate and competitive. This is unfortunate because they complement each other in almost every way. The response of sensitive indicator organisms to an environmental stress provides an early result. Organisms are uniquely sensitive to multiple environmental stresses operating consecutively or simultaneously. They also integrate the effects of these environmental stresses over time. The ability to selectively accumulate, biomagnify, and show the synergistic effects to exposure from environmental stresses gives bioindicators uniquely useful properties.

The slow recognition of the utility of biological monitoring techniques may be, in part, a result of the difficulty in obtaining quantitative numbers and levels that can be used in a manner similar to that for data obtained by chemical and physical procedures. To some extent, these problems are being solved through the standardization of both laboratory bioassays and in situ biological measurement. Also, increasing sophistication in data collection and interpretation and information on trends in population diversity of ecosystems are providing useful information. Rapid developments and massive amounts of information being gathered through the interdisciplinary activities in federal, state, industry, and academic programs need to be synthesized and documented on a continuing basis.

Aquatic biologists, ecologists, and plant biologists are among those groups of scientists who have been actively developing biological monitoring methods to determine the effects of human activities on biological systems. Communication among these groups has been sporadic at best. One reason for this is the traditional natural inertia between scientific disciplines. Each has its own problems, concerns, and goals that also extend to biological monitoring.

Although the definitions, scope, and roles for biological monitoring have frequently been subjects for discussion within each of the above groups, these groups rarely deliberated on issues of mutual concern. This was one of the primary reasons for planning this book.

Whenever there is a meeting on biological monitoring, the subject of an appropriate definition for biological monitoring is considered. Dr. Cairns offered this useful definition in his provocative presentation: "Biological monitoring is the regular application of biological techniques and methods to determine information about the quality and condition of a biological system." This definition should also be compatible with the purpose that ecologists have applied to biological monitoring, that is, to "monitor the structure and function of natural ecosystems," and to others who use biological indicators for measuring the levels and distribution of environmental contaminants.

Two very real concerns were expressed by several contributors:

1. The lack of clear recognition of biological monitoring in preparing federal and state legislative acts and in environmental regulations. As a result, both funding and staffing are inadequate to do an effective effort in monitoring for effects.
2. The feeling on the part of some scientists that biological monitoring is for applied university-type research or course of instruction.

Fortunately, inroads are being made on both issues. Dr. Buffington elaborated on the efforts of the Council of Environmental Quality to improve overall national environmental-monitoring efforts. It is anticipated that their recommendation will eventually be reflected in a more significant role for biological monitoring in federal research and regulatory control activities.

The rapid progress and growing interest in biological monitoring and the growing need to understand both the subtle and the more obvious effects of stresses we apply to various sensitive species and to biological systems require that universities recognize this area as an integral part of their educational and research activities.

Acknowledgments

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The editor wishes to express deep appreciation to the directors and able staff of the Water Resources Research Institute of The University of North Carolina, Raleigh, and especially to Ms. Linda Kiger, administrative officer, and to the efficient, effective assistance received from the head secretary, Ms. Eva McClung.

Contents

Part I
Introduction and Overview

The chapters in part I review the philosophical and scientific basis for using biological indicators to monitor the bioeffects of human activities on people and the ecology. One author suggests that biological monitoring is a useful means of measuring people's symbiotic relationship with their natural environment.

The need to reverse a growing public skepticism toward information generated from environmental monitoring programs and the role of biological monitoring in providing more credible bioeffects data is noted. Efforts to upgrade national environmental monitoring programs are described, and alternative futures for biological monitoring are presented. The use of monitoring data in formulating regu atory and legislative environmental policy decisions and in evaluating trends in the quality of our environment is observed. A need to standardize tried and proved biomonitoring methods is discussed.

1 Introduction

Joab Thomas

There are indications of a growing age of skepticism with regard to monitoring the effects of hazardous pollutants in our environment. This may be the result of overreacting on the part of overzealous environmentalists. But for the most part, we have simply been made aware in a number of ways of hazards in the environment. Unfortunately, many people are unable to understand how these hazards affect their lives or what they can do about them. We need to guard against skepticism that develops as the result of misunderstandings or because of inaccurate or misleading information on the effects of these environmental contaminants. A recent newspaper advertisement in Mississippi read, "Azaleas for Sale, Not Known to Cause Cancer."

This was amusing, perhaps, but the depth of meaning went a lot further. We do have this growing skepticism in public attitudes toward alleged effects of environmental monitoring data of various sorts. It is unlikely, however, that there will be much of this skepticism about effects information obtained by biological monitoring methods, since this involves observing the effects of toxic substances on living systems. As we become more sophisticated and able to achieve useful and often quantitative data using biologically sensitive systems, we should have available a network of built-in "smoke detectors" all around the country to give us early warning of pending hazards from environmental pollution.

In North Carolina, for the most part, we still have a relatively clean environment with some time left and the opportunity to guide population and industrial growth so the environment in our state does not become inhospitable to biological systems, including people. We should monitor the effects of our rapid population and industrial growth before it is too late. To do this, it will be necessary to develop and put into effect a credible biological monitoring system.

Hopefully, we can reverse this growing trend toward skepticism in our environmental monitoring programs and develop a sense of reality that will enable us to design and engineer our future rather than to become victims of it.

2 A Review of Environmental Data and Monitoring

John D. Buffington

The President's 1977 Environmental Message[1] provides a useful guide for studies and implementation of changes and improvements in federal programs to maintain the quality of our environment. His message also incorporates innovative administrative initiatives in the environmental area. Some of these have already been brought to satisfactory completion, and others are still in process.

The Council on Environmental Quality (CEQ) received several directives in this message that relate to environmental data and monitoring. Attention was called to large gaps or overlaps in coverage, to poor-quality assurance in data, and to the lack of coordination among laboratories. Also, in many cases, the data obtained suffered from inadequacies in programmatic design. As a result, our environmental monitoring data do not provide federal, regional, or state planning officials with the information they require to assess trends in the quality of the environment or to take legal ameliorative or other needed actions.

In response to the President's request, the Council on Environmental Quality organized an Interagency Task Force on Environmental Data and Monitoring, consisting of five working groups in ecology, air, water, socioeconomics, and land use. Several of the authors of this book are participants in this effort.

One of the problems we immediately encountered is that there is no commonly accepted definition of monitoring. With a great deal of effort, we developed the following: *Environmental monitoring* is the systematic and repetitive collection and analysis of data which can be used (1) to help determine the quality of the environment or condition of natural resources as they are or will be and (2) to help relate environmental quality or natural resources to factors which cause them to change or to effects produced by such changes.

Monitoring is not an end in itself. It is only a means for providing data and analytical information for other functions. For example, three functions support environmental monitoring:

1. Environmental policy and management decisions, including definitions of federal program objectives and priorities and selection of specific regulatory or enforcement actions
2. Identification and definition of environmental problems which are not now recognized or may emerge in the future
3. Evaluation of "progress" in environmental quality as a result of specific federal policies, programs, or actions

Major components of the environmental monitoring process include monitoring design, quality assurance, data management, data analysis, research and development in support of data collection and interpretation, coordination of agency activities, and the review, dissemination, and use of the resulting information.

All you have to do is read the magazines of environmental organizations to realize the frequent dissatisfaction of the private public-interest groups with the way many of our resource decisions are being made. In many cases, it is because the decisions are made in a data-poor environment. The Council on Environmental Quality encourages federal agencies to base their environmental decisions on the soundest possible scientifically valid data.

Major legislation is passed every year assigning tasks to major federal agencies that result in the acquisition of large amounts of environmental data. There is a real need to obtain a clearer picture of what is happening to the nation's environment. It is easier to do this with air quality and water quality information since there are national networks of stations gathering data which are roughly comparable with one another. Many of these data sit in readily available data banks such as STORET and SAROAD. In some cases, the collection method, the frequency of data input, and the institution collecting the data can be made available so that users of these data banks can make independent decisions as to whether the data are valid. For example, CEQ has done precisely this by screening the air and water data through a set of criteria to provide additional quality assurance to erect data sets for analysis in its UPGRADE data analysis systems.[2] Now that this is done, certain questions can be asked. For example, is air quality getting better in five major metropolitan areas or water quality getting worse east of the Mississippi? Are municipal sewage treatment plants helping the nation's water quality situations? Those who have perused the annual reports of the Council on Environmental Quality have seen extensive analyses of such hypotheses for both air and water quality status and trends. These analyses are based on our UPGRADE data sets derived from the Environmental Protection Agency SAROAD and STORET systems.

Those of us who are dealing with *ecological* monitoring, which approximates the biomonitoring topic of this book, have more problems with the definitions of monitoring than those professionally working with air and water quality. For example, although there is much wildlife management information, it is not gathered to assess long-term changes in natural biota. Consequently, little information is available about regional trends and almost none about national trends. Many professionals do not regard such data as constituting ecological monitoring data. Some ecological monitoring programs are not regarded as "ecological" by the performing agencies. Other programs are largely research-oriented.

Each of the working groups is preparing initial analyses of about a dozen issues. These are described in Appendix 2A. These will be synthesized into option papers which will be the basis for implementing changes. In addition, each working group is dealing with several issues proper to its own area.

Several of these issues are being developed by the ecological working group. For example, the need for a program to provide long-term data to monitor

the status trends of ecosystems is widely recognized. Currently, the groups dealing with man and the biosphere and the experimental ecological reserves are addressing this issue to some extent. Our study team will examine these programs among others to see precisely what our needs are and identify the best means of satisfying them.

Another topic which is under study is whether a national ecological service is an idea whose time has come. This was first recommended in *The Role of Ecology in the Federal Government.*[3]

A topic of immediate pertinence to this book is impact assessment monitoring. Several recent symposia, including one sponsored by CEQ at the 1976 American Institute of Biological Sciences (AIBS) meeting, have already addressed this topic. There appears to be consensus that improvements are possible. We will suggest a program of specific recommendations.

In inventorying ecological monitoring programs, we found that many agencies do not have monitoring as a discrete budget item. Also much of what is going on in the monitoring area is taking place in regional organizations of federal agencies. These regional organizations themselves do not have monitoring broken out in their budget. In some cases, the regional budgets of agencies are lost at the federal level. We dealt as best we could with these problems and assembled an inventory which describes as a first cut the ecological monitoring taking place in the federal system. Unfortunately, it is very difficult even to precisely identify the resources being applied in this area.

Preliminary results of our effort suggest that ecological monitoring is where air and water monitoring were perhaps twenty years ago. This accounts for the large research component and the lack of centralized focus. Moreover, there is no overriding legislative mandate such as there is for the physical media. However, I anticipate that the progressive suggestions and contributions made in this book will help to evolve and systemize our thinking on this subject of biological monitoring.

Notes

1. The President's Environmental Program, Washington: Government Printing Office, 1977.

2. The *U*ser *P*rompted *GRA*phic *D*ata *E*valuation system was developed by CEQ with Environmental Protection Agency and Department of Energy cosponsorship and the participation of other agencies. It is completely user-oriented since it is English-prompted and requires no specialized knowledge of computer language. It permits rapid graphic and statistical analysis of environmental data.

3. Council on Environmental Quality and Federal Council for Science and Technology, *The Role of Ecology in the Federal Government*, December 1974.