

*New Approaches  
to Monitoring*  
**AQUATIC  
ECOSYSTEMS**

**Terence P. Boyle**  
*editor*

 **STP 940**

# NEW APPROACHES TO MONITORING AQUATIC ECOSYSTEMS

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# Foreword

This publication, *New Approaches to Monitoring Aquatic Ecosystems*, contains papers presented at the symposium on Long-Term Monitoring of Aquatic Ecosystems, which was held in Minneapolis, Minnesota, 17–21 June 1985. The symposium was sponsored by ASTM Committee E-47 on Biological Effects and Environmental Fate and by the Applied Ecology Section of the Ecological Society of America. Terence P. Boyle, National Park Service, presided as symposium chairman and was editor of this publication.

## **Related ASTM Publications**

**Rationale for Sampling and Interpretation of Ecological Data in the Assessment  
of Freshwater Ecosystems, STP 894 (1986), 04-894000-16**

**Community Toxicity Testing, STP 920 (1986), 04-920000-16**

## A Note of Appreciation to Reviewers

The quality of the papers that appear in this publication reflects not only the obvious efforts of the authors but also the unheralded, though essential, work of the reviewers. On behalf of ASTM we acknowledge with appreciation their dedication to high professional standards and their sacrifice of time and effort.

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# Overview

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Three areas of concern have developed within the last several years that have forced an evolution of strategies within the field of environmental monitoring. The first is the complex problem of regulation of the extensive use of chemicals in environmental management and the increasing awareness of the magnitude of fugative chemicals present in the environment as contaminants. Monitoring these chemical residues in the environment, as well as establishing their range of effects in the ecosystem, has become the focus of a number of programs of state and federal agencies.

The second factor prompting reconsideration of environmental monitoring was a general criticism of water quality data collection programs by scientists and managers. These criticisms were presented in the two-volume 1982 report to the U.S. Congress by the comptroller general entitled, "Better Monitoring Techniques Are Needed to Assess the Quality of Rivers and Streams." The report summarized three issues: (1) the complexity of defining water quality; (2) the inability of the then existing fixed-station, fixed-interval sampling networks to assess water quality; and (3) field and laboratory methodological inconsistencies yielding poor data. The report recommended development of specialized programs to address specific issues of water quality and the development of biological indicators to define water quality criteria.

The third factor was the realization among ecological researchers of the high degree of temporal variability in important components of natural ecosystems. In order to adequately determine trends, cycles, and patterns in these systems, research efforts would need to become longer and would need to develop a rationale for monitoring in a research framework. These research needs were recognized by the selection of eleven sites and by funding for suitable time frames by the National Science Foundation's Long-Term Ecological Research Program.

This volume represents recent state-of-the-art research in the field of environmental monitoring that is a direct result of awareness of these concerns. The purpose of this collection of papers is to provide a range of examples of areas where new methods and approaches of environmental monitoring are being employed. This volume is intended for scientists, who will design monitoring programs as part of their research, and for environmental managers, who initiate the questions for monitoring and who would be the ultimate users of the results. The papers in this volume elaborate specific concerns, questions, and program criteria that characterize the inception of developing monitoring programs and provide specific examples as paradigms for future monitoring programs.

The first paper by Murray introduces the National Fisheries Survey conducted cooperatively by the U.S. Fish and Wildlife Service and the Environmental Protection Agency. This survey monitoring program uses the status of environmentally sensitive sport fish communities arranged in a comprehensive geographic statistical design as a summary biological indicator of the health of the nation's streams and rivers. The program, instituted in 1983, can also be used to determine long-range trends in regional water quality.

The paper by Segar et al. elaborates criteria to be considered in long-term pollution monitoring programs. Specific elements include management considerations, the development of appropriate bioindicators, statistical design and hypothesis testing, criteria for the selection of bioindicator species, and considerations for selecting sampling sites. Monitoring coastal pollution is presented as an example of a program manifesting these characteristics.

Questions concerning the management of water quality are often implicit in this design of data collection programs, and yet often monitoring programs are ultimately found to be useless by the resource managers they are supposed to inform. Perry et al. develop a framework for the development of management-oriented goals in monitoring programs in the form of an environmental audit that forces managers and scientists into a dialogue concerning the explicit management questions, the monitoring required, and the nature and limitation of the data collected.

Trends in atmospheric deposition from the recent past and in the future need to be compared with an established historical trend to be environmentally interpretable. Ombrotrophic bogs receive all their water and materials from atmospheric sources and can be used to monitor atmospheric deposition of acid and heavy metals. Norton and Kahl develop the technique of using peat bogs as long-term trend records for the assimilation of trace metals associated with fossil fuel combustion and smelting and compare their methods with techniques using lake cores to monitor lead, zinc, and vanadium.

Some of the most remote, pristine areas of North America are potentially threatened by atmospheric-born pollutants. Larson presents research efforts to document change in Crater Lake, Oregon from information in a number of piecemeal studies and presents the formulation of a long-term monitoring program using a number of components of the phytoplankton, zooplankton, and fish community. This paper introduces the beginning of a ten-year congressionally mandated research monitoring program.

The use of simple, socially relevant, management-oriented methods are presented by O'Connor and Flemer. An example of one such model is the characterization of geographical prevalence of fin erosion in winter flounder along the Northeast Coast of the United States. Emphasis on field population-level effects represents the change in monitoring emphasis from laboratory bioassays toward ecosystem-level assessment.

Degradation of large aquatic systems usually occurs over the course of several decades of environmental abuse. Similarly, the implementation of mitigation

practices and restoration takes place over relatively long periods of time. Mountford and Mackiernan present the description and results from a network of 167 monitoring stations designed to monitor environmental conditions in Chesapeake Bay for several decades. The effort represents cooperative monitoring of two states, several research laboratories, and the U.S. Environmental Protection Agency and is aimed at providing information on the efficacy of a number of pollution control measures in the surrounding area.

Phelps et al. present a monitoring program designed to detect pollution in coastal waters using quantified responses at the cellular, tissue, whole organism, and population level of organization of the blue mussel. Specific responses were compared with body burdens for several sets of organic chemicals and selected heavy metals. The monitoring scheme employs four levels of effort that correspond to different levels of contamination and are formalized in a conceptual model with information feedback loops.

Farrington et al. review the history of the development of the sentinel organism monitoring strategy using several species of bivalves to identify contaminated coastal areas. The Mussel Watch Program has been used to monitor long-term trends in the bioaccumulation of selected organic chemicals and heavy metals along the Northeast Atlantic Coast since 1976. They discuss the strengths and limitations of using the sentinel organism concept in the context of national and multinational programs.

Biological monitoring at the population and community level of organization requires intensive long-term data collection efforts. Hines et al. address the problem of statistical resolution for sampling estuarine invertebrates and fish in long-term, six-year studies of population abundance and community composition. Their extensive study is important in delineating the magnitude of natural variation of community composition in time, measure of change associated with natural and manmade gradual trends and catastrophes, and the importance of long-term studies for testing causal mechanisms controlling populations abundance based on correlative relationships with environmental variables.

The detection and tracing of complex organic chemical residues, with multiple groups and isomers from nonpoint sources or transported through the atmosphere, requires not only adequate field monitoring but also the application of specialized analytical and numerical techniques. Petty et al. present an integrated technique using information on residue analysis generated by gas chromatography to determine the source of toxaphene residues analyzed in fish tissues collected in monitoring programs in the Great Lakes, in Siskiwit Lake on Isle Royale, and in rivers in the southeastern United States. The use of multivariate pattern recognition technique applied to the data complex generated from the analytical chemical procedures enabled the investigators to compare chemical and isomeric constituents and conclude that organochlorine complex detected in the monitoring program was toxaphene and from a common source.

One of the problems confronting both managers and scientists in compiling data sets from long-term research monitoring programs is how to manage and

analyze long-term ecological data bases. Michener et al. present the rational framework for a data management system that incorporates data sets with a high degree of temporal variability and which requires analysis by a variety of software programs, including complex multivariate and cartographic analysis, data base manipulation, and ecosystem modeling. They have developed an integrated system currently in use by an interdisciplinary research team at the Long-Term Ecological Research Program site in North Inlet, South Carolina.

The final paper by Stottlemeyer addresses one of the most fundamental and most frequently overlooked aspects of data gathering in any research or monitoring effort: quality assurance–quality control procedures for the ensuring of data integrity. He has developed a strategy and a set of criteria for long-term ecosystem monitoring which includes compatibility of instrumentation, consistent collection procedures, and protocols to integrate formats of field and laboratory technique and data entry to ensure compatibility. The quality assurance–quality control system depends on a series of formal internal and external audits to maintain the integrity of the final data.

From this set of papers on various aspects of environmental monitoring three areas of research needs emerge: (1) development of specific sets of procedures to determine the minimum data requirement for specific programs; (2) development of new sets of biological indicators with sensitivity response to different aspects of water quality; and (3) development of formal procedures that integrate the concerns of environmental managers with the expertise of environmental scientists.

The field of environmental monitoring is very much a synthetic science and the future will see even more interdisciplinary collaboration and the application of new technological advances.

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