BIOLOGICAL RESPONSE SIGNATURES

Indicator Patterns Using Aquatic Communities

BIOLOGICAL RESPONSE SIGNATURES

Indicator Patterns Using Aquatic Communities

Thomas P. Simon

CRC PRESS

Boca Raton London New York Washington, D.C.

Cover Illustrations: Rainbow Darter, Southern Redbelly Dace, and Rock Bass (© Joseph R. Tomelleri). Euglenoid (*Trachelomonas armata* (Ehr.) Stein) courtesy of Philadelphia Academy of Natural Sciences.

Library of Congress Cataloging-in-Publication Data

Biological response signatures : indicator patterns using aquatic communities / edited by Thomas P. Simon.
p. ; cm.
Includes bibliographical references (p.).
ISBN 0-8493-0905-0
1. Indicators (Biology) 2. Water quality biological assessment. 3. Aquatic ecology. I. Simon, Thomas P.
QH541.15.I5 B56 2002
577.6'028'7—dc21 2002276541
CIP

No claim to original U.S. Government works
International Standard Book Number 0-8493-0905-0
Library of Congress Card Number 2002276541
Printed in the United States of America 1 2 3 4 5 6 7 8 9 0
Printed on acid-free paper

Foreword

Biological indicators have become primary measures of the conditions of our water resources. The integration of biological assessments and criteria into water quality management programs worldwide is impressive. Whether freshwater or coastal, running waters or wetlands, biological indicators have transcended the difficulties in communicating their results by the adoption and refinement of indices of biotic integrity (IBIs). IBIs have been developed for fish, macroinvertebrates, periphyton/diatoms, macrophytes, and even birds and terrestrial ecosystems. The key remaining challenge for such biological indicators is diagnostic — to demonstrate clearly the causes and effects needed to take actions to protect and restore water resources. *Biological Response Signatures* by Dr. Thomas Simon helps to meet this challenge by presenting an unprecedented compilation of technical approaches and case studies that allow the reader to better understand biological response signatures and stressor identification and how they can be applied successfully in other programs.

The United States Environmental Protection Agency (USEPA) has been particularly interested in identifying specific stressors that cause impairment to aquatic communities. It published a *Stressor Identification Guidance Document* with a logical approach to evaluating evidence and identifying the main stressors causing biological impairments. In fact, several issues surrounding the total maximum daily load (TMDL) regulation and guidance directly affect biological indicators. Most recently, USEPA has decided that a TMDL does not need to be developed if a pollutant cannot be identified as the stressor causing biological impairments. Therefore, although a TMDL may not be required, it is imperative to determine the real cause of impairment to the biological community, whether the stressor is chemical contamination, nutrient enrichment, poor habitat quality, or hydrologic alteration.

Biological Response Signatures takes this discipline to the next level, just as Dr. Simon's last effort, *Assessing the Sustainability and Biological Integrity of Water Resources Using Fish Communities,* has become the standard reference for fish community assessment. From the conceptual framework to the case studies, this book provides those key elements to support better diagnostic evaluations of the stressors to biological communities.

Wayne S. Davis
United States Environmental Protection Agency
Washington, D.C.

Preface

The primary purpose of this book is to further the technical knowledge of biological indicators necessary to assess the causes and sources of environmental effects. In an effort to do this, I have built from two previous texts I was involved with and attempt to supply the reader with new information and relevant summaries. Although this book is not comprehensive, I have encouraged the chapter authors to include relevant ideas and information. This book does not review the status of biocriteria nor their underpinnings (see Karr, 1981; Karr et al., 1986; and Karr and Chu, 1999). Those interested should consult Davis and Simon (1995) for information on application and background. This book does not attempt to review the status of multimetric indices for all biological indicator assemblages (see Simon, 1999, for additional information on fish assemblage indicator development).

Rarely are environmental impacts the results of single chemical or even single industrial sources; rather, they are complex mixtures and interactions of contaminants. The use of environmental assessment procedures within monitoring frameworks demands some relevancy to the decisions based on biological criteria that management agencies make. These biological criteria standards are the basis for environmental indicators that provide direct measures of environmental quality.

The use of biological criteria in monitoring and assessment programs resulted from the impressive degree of precision that can be achieved with the index of biotic integrity (IBI). The IBI was originally developed by James R. Karr (1981) to evaluate midwestern stream fish assemblages. This single index has been further developed to represent a full range of issues that explain biological integrity (Fausch et al., 1984, 1990; Angermeier and Karr, 1986; Angermeier and Schlosser, 1987; Karr et al., 1986; Simon, 1999).

The IBI is considered a multimetric index; it represents a family of indices adapted for use in organismal indicator groups besides fish. Simon (2000) indicated that the IBI is one single type of biocriterion. I suggested that our tool boxes contain a wide range of biological indicators including diversity indices (e.g., Shannon-Weiner diversity index), univariate indices (e.g., species richness indices, Hilsenhoff biotic index, index of well-being), the widely adapted multimetric indices of biological integrity for a variety of indicator assemblages (e.g., Karr, 1981; Karr et al., 1986; Simon and Lyons, 1995; Simon, 1999; Simon et al., 2001), and indices of sustainability (e.g., tailwaters index, reservoir fishery assessment index; included in Simon, 1999) in order to make accurate assessments.

This book was begun to evaluate what is known about patterns in multimetric indices relating to known point or non-point source impacts. It focuses on the IBI, but I attempted to include viewpoints related to other univariate and multivariate approaches as well. Current research on environmental assessment patterns has not kept pace with the prognosis of environmental health and condition (USEPA, 2000). This book is state-of-the-art and describes the results of years of biological indicator development; it is the first to address patterns in multimetric indices based on site assessment. It attempts to evaluate the differences in biological integrity between natural and altered landscapes and discusses the types of organismal indicator groups used for assessments of diatoms, aquatic macrophytes, aquatic invertebrates, mussels, fish, amphibians, and birds.

The 26 chapters in this book are designed to build on the foundation established by *Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making* (Davis and Simon, 1995). That book described the foundational concepts and background necessary to utilize fully the ideas presented in this volume. It was used by many resource agencies, researchers, and in college classrooms to teach the next generation of environmental scientists and biologists a wide range of issues ranging from environmental assessment to natural resource decision making and ecosystem management.

This book does not repeat information contained in *Assessing the Sustainability and Biological Integrity of Water Resources Using Fish Communities* which highlighted a number of inconsistencies, including the lack of information on framing points such as zoogeographic implications to developing reference conditions, differences between biological integrity of altered environments and natural habitats, inaccurate or misinformation in guild descriptions and classifications that are the premises behind the various metrics, and application of the index to areas other than small warmwater streams. I have divided this book into five sections: (1) conceptual framework, (2) contaminant patterns in ecosystems, (3) method advancement, (4) land use modification patterns and effects of non-point sources, and (5) case studies.

The conceptual framework section (Chapters 1 through 4) discusses ideas behind biological response signatures. Following are a series of chapters that describe ramifications of the environmental relevancy of biological criteria, biological stress responses, use of multiple indicators to diagnose biological response patterns, and setting restoration and ecological recovery endpoints using biological criteria. The use of biological response signatures and advancing the efforts to understand changes in community response to anthropogenic disturbance will probably require major efforts in future years.

The majority of regulatory agencies are in the process of developing response indicators based on reference conditions or reference sites within regional frameworks and calibrated multimetric indices. Changes in assemblage indicators must be able to separate natural variability from human disturbance gradients. Cairns describes the effects of environmental stress and the unique abilities of biological organisms to detect and diagnose these changes. The state of Ohio has been a model for other states in the area of understanding and evaluating processes and how they might work within a regulatory framework. Sources of impairments are presented using a series of case studies that reflect a variety of stressor responses. The last chapter in this section describes how biological criteria and indicators can be used to diagnose the degree of impact and determine appropriate restoration goals and options. These ecological recovery endpoints can be used to determine when restoration as a result of total maximum daily load (TMDL) and national pollutant discharge and elimination (NPDES) permit limits are in compliance or when, after an oil or major spill, the environment has fully recovered.

The contaminant patterns in the ecosystems section (Chapters 5 through 8) describes patterns from specific effects on different organism groups. Contaminated dredge spoil effects on wetland plant communities, the effects of depth of fines on aquatic ecosystem health, pesticide effects on assemblages, and metal contamination of macroinvertebrate assemblages are highlighted. These chapters are paired with case studies in Sections IV and V that describe specific applications. Limited information on large-scale cutting edge issues such as sediment quantity effects and new generation pesticides is available. Likewise, the extensive degradation of wetland plant assemblages and metal effects on trophic dynamics in aquatic systems result from sediment and water degradation that affects thousands of stream miles.

The method advancement section (Chapters 9 through 12) discusses assessment approaches and evaluates specific IBI metric relationships with human disturbance. The assessment of point source impacts has classically been monitored using a simple upstream versus downstream approach. This assessment approach is not necessarily effective for testing metric response and determining whether the IBI reveals noise or natural variability. The use of the new traveling zone (T-zone) approach was applied to assessments on the Ohio River. Pioneer species have classically been used to evaluate headwater streams, but do they have a wider application?

Rankin and Simon evaluate patterns in Ohio streams and rivers and specifically assess four case studies. Thoma and Simon evaluate preliminary patterns observed in the Great Lakes and correlations between omnivores and nutrient stimulation. The need for USEPA and the U.S. Department of Agriculture to establish protective nutrient criteria caused interest in evaluating specific patterns between fish assemblage structure and function and nutrient stimulation. The future of biocriteria and biological integrity assessment is presented in the chapter by Wiley et al. They show how using a model of stream integrity based on geographic information system technology and an extensive database from Michigan revealed predicted versus observed effects in streams in the lower peninsula.

The land use modification patterns and effects of non-point sources section (Chapters 13 through 18) represent a variety of non-point source impact types from urbanization to mining, pesticide application, and land use changes as a result of confined disposal facilities (CDFs). Wang and Lyons review the resultant impacts of urbanization and how they may impact biological integrity. The relevant question becomes whether urban streams can attain the same levels of biological integrity they formerly had as natural streams.

Wilhelm et al. describe the recovery of seral soils after impacts and management of confined disposal facilities. Their studies in the Great Lakes show that limited recovery of wetland assemblages occurred in these CDFs. Carlisle et al. evaluated the effects of aerial deposition and former land use changes in the Cuyahoga National Park as a result of heavy metals, polyaromatic hydrocarbons (PAHs), and mercury. They evaluated the ability of benthic macroinvetebrate assemblages to detect changes and effects that could assist in the recovery of these systems.

Hard rock mining impacts in the western United States greatly impacted large expanses of land. Mebane and Fore describe issues surrounding hard rock mining impacts in Idaho and Colorado streams using macroinvertebrate assemblages. Lydy et al. conducted a case study in Kansas to evaluate patterns in IBI metrics with pesticide residues in fish tissue and sediment. Simon and Exl evaluated patterns in silviculture impacts on stream communities related to water quality, habitat changes, and biological indicators.

The last section of the book (Chapters 20 through 26) deals with case studies. Impacts that result from confined animal feedlots, iron and steel manufacturing, acid mine leachate and acid rain, thermal discharge, and agriculture, urbanization, and coal mining are described. Many chapters in this section are based on multiple indicator groups and provide a wealth of information on responses. Several chapters include information on point source discharge, including two chapters on iron and steel manufacturing in southern Lake Michigan and discharge effects on fish and thermal effects on fish and macroinvertebrate assemblages in the Ohio River drainage. The testing and patterns in diatom assemblages in the Appalachian Mountains were evaluated, while multiple indicators in this same region were evaluated for response signatures.

This book is the beginning of further work using aquatic assemblages as environmental indicators of biological integrity. It is my hope that environmental managers, biologists, hydrologists, and others using this book will benefit from the experiences of the authors who are at the forefront of this field. Although this book puts into perspective how much is known about response patterns and environmental assessment, additional work is required to answer remaining questions. Historically, many disciplines worked in isolation — concerned only with their own indicators. We now know that many groups observe similar patterns and responses. It is with great pleasure that we continue our attempts to provide an accurate prognosis on the condition of our environmental resources in an effort to restore, protect, and enhance the biological integrity of our nation's surface waters.

REFERENCES

Angermeier, P.L. and J.R. Karr. 1986. Applying an index of biotic integrity based on stream fish communities: considerations in sampling and interpretation, *North American Journal of Fisheries Management*, 6, 418–429.

Angermeier, P.L. and I.J. Schlosser. 1987. Assessing biological integrity of the fish community in a small Illinois stream, *North American Journal of Fisheries Management*, 7, 331–338.

Davis, W.S. and T.P. Simon, Eds. 1995. *Biological Assessment and Criteria: Tools for Water Resources Planning and Decision Making*. Lewis Publishers, Boca Raton, FL.

Fausch, K.D., J.R. Karr, and P.R. Yant. 1984. Regional application of an index of biotic integrity based on stream fish communities, *Transactions of the American Fisheries Society*, 113, 39–55.

Fausch, K.D., J. Lyons, J.R. Karr, and P.L. Angermeier. 1990. Fish communities as indicators of environmental degradation, in S.M. Adams (Ed.), *Biological Indicators of Stress in Fish*. American Fisheries Society Symposium 8, Bethesda, MD, 123–144.

Karr, J.R. 1981. Assessment of biotic integrity using fish communities, *Fisheries*, 6, 21–27.

Karr, J.R. and E.W. Chu. 1999. *Restoring Life in Running Waters: Better Biological Monitoring.* Island Press, Washington, D.C.

Karr, J.R., K.D. Fausch, P.L. Angermeier, P.R. Yant, and I.J. Schlosser. 1986. *Assessing Biological Integrity in Running Waters: A Method and Its Rationale*. Illinois Natural History Survey Special Publication 5, Champaign, IL.

Simon, T.P., Ed. 1999. *Assessing the Sustainability and Biological Integrity of Water Resources Using Fish Communities.* CRC Press, Boca Raton, FL.

Simon, T.P. 2000. The use of biological criteria as a tool for water resource management, *Environmental Science and Policy,* 3, S43-S50.

Simon, T.P. and J. Lyons. 1995. Application of the index of biotic integrity to evaluate water resource integrity in freshwater ecosystems, in Davis, W.S. and T.P. Simon, Eds. *Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making.* Lewis Publishers, Boca Raton, FL.

Simon, T.P., P.M. Stewart, and P.L. Rothrock. 2001. Development of multimetric indices of biotic integrity for riverine and palustrine wetland plant communities along southern Lake Michigan, *Aquatic Ecosystem Health and Management*, 4, 293–309.

U.S. Environmental Protection Agency. 2000. *Stressor Identification Guidance Document*. EPA 822/B-00/025. USEPA, Office of Water, Washington, D.C.

Acknowledgments

I gratefully acknowledge the chapter authors for their efforts and dedication at completing the task at hand. Chapters affiliated with the U.S. Environmental Protection Agency, U.S. Geological Survey, and U.S. Fish and Wildlife Service were part of the official USEPA, USGS, and USFWS peer review process, and those reviewers are acknowledged.

I want to thank my wife and children for their support. I especially want to thank my wife who provided enormous strength for this project. Without her encouragement, support, and handling the additional load of our daily family activities, I would never have been able to complete this task.

I wrote portions of this book and edited it in my private capacity. No official support or endorsement by the U.S. Environmental Protection Agency, the U.S. Fish and Wildlife Service, or any other agency of the federal government is intended or should be inferred.

Contributors

Holly H. Bennett
Department of Biological and Environmental Sciences
Troy State University
Troy, Alabama

Sandra A. Bryce
Dynamac Corporation
Corvallis, Oregon

Jason T. Butcher
U.S. Forest Service
Superior National Forest
Duluth, Minnesota

John Cairns, Jr.
Virginia Polytechnic Institute and State University
Department of Biology
Blacksburg, Virginia

Daren M. Carlisle
U.S. National Park Service
Omaha, Nebraska

William H. Clements
Colorado State University
Department of Biology
Fort Collins, Colorado

Jeffrey S. DeShon
Ohio Environmental Protection Agency
Division of Surface Water
Groveport, Ohio

Ronda L. Dufour
Dufour Consulting
Indianapolis, Indiana

Erich B. Emery
Ohio River Valley Water Sanitation Commission
Cincinnati, Ohio

Joseph A. Exl
U.S. Fish and Wildlife Service
Bloomington, Indiana

Wayne C. Faatz
Indiana Department of Natural Resources
Indianapolis, Indiana

Leska S. Fore
Statistical Design, Inc.
Seattle, Washington

James R. Gammon
Department of Biological Science
DePauw University
Greencastle, Indiana

Eric L. Garza
U.S. Geological Survey
Lake Michigan Ecological Research Station
Porter, Indiana

Mary G. Henry
U.S. Fish and Wildlife Service
Washington, D.C.

Robert M. Hughes
Dynamac Corporation
Corvallis, Oregon

Krzysztof M. Jop
Marion, Massachusetts

Peter M. Kiffney
Northwest Fisheries Science Center
Seattle, Washington

Michael J. Lydy
Department of Zoology
Southern Illinois University
Carbondale, Illinois

John Lyons
Fish and Habitat Research Section
Wisconsin Department of Natural Resources
Monona, Wisconsin

Frank H. McCormick
U.S. Environmental Protection Agency
Cincinnati, Ohio

Joan S. Martin
Huron River Watershed Council
Ann Arbor, Michigan

Christopher A. Mebane
Idaho Department of Environmental Quality
Boise, Idaho

Charles C. Morris
Department of Biological and Environmental Sciences
Troy State University
Troy, Alabama

Steven A. Newhouse
Indiana Department of Environmental Management
Indianapolis, Indiana

Edward T. Rankin
Ohio Environmental Protection Agency
Division of Surface Water
Groveport, Ohio

Christy D. Robinson
Department of Biological and Environmental Sciences
Troy State University
Troy, Alabama

James A. Sawyer, IV
Department of Biological and Environmental Sciences
Troy State University
Troy, Alabama

Paul W. Seelbach
Institute for Fisheries Research
Ann Arbor, Michigan

Thomas P. Simon
U.S. Fish and Wildlife Service
Bloomington, Indiana

Scott A. Sobiech
U.S. Fish and Wildlife Service
Carlsbad, California

Daniel W. Sparks
U.S. Fish and Wildlife Service
Bloomington, Indiana

Paul M. Stewart
Department of Biologcal and Environmental Sciences
Troy State University
Troy, Alabama

Roger F. Thomas
Ohio Environmental Protection Agency
Division of Surface Water
Twinsburg, Ohio

Jeffrey A. Thomas
Ohio River Valley Water Sanitation Commission
Cincinnati, Ohio

Lizhu Wang
Wisconsin Department of Natural Resources
Fish and Habitat Research Section
Monona, Wisconsin

Kevin Wehrly
Institute for Fisheries Research
Ann Arbor, Michigan

Gerould S. Wilhelm
Conservation Design Forum, Inc.
Elmhurst, Illinois

Michael J. Wiley
The University of Michigan
School of Natural Resources and Environment
Ann Arbor, Michigan

Chris O. Yoder
Midwest Biodiversity Institute
Columbus, Ohio

Reviewers

Loren L. Bahls
Hannaea
Helena, Montana

William H. Clements
Colorado State University
Department of Biology
Fort Collins, Colorado

Darla Donald
Virginia Polytechnic University
Department of Biology
Blacksburg, Virginia

Ronda L. Dufour
Dufour Consulting
Indianapolis, Indiana

Leska S. Fore
Statistical Design, Inc
Seattle, Washington

James R. Gammon
Department of Biological Science
DePauw University
Greencastle, Indiana

Mary G. Henry
U.S. Fish and Wildlife Service
Washington, D.C.

Alan Herlihy
Oregon State University
Department of Fish and Wildlife
Western Ecology Division
Corvallis, Oregon

Robert M. Hughes
Dynamac Corporation
Corvallis, Oregon

Phil Kaufmann
U.S. Environmental Protection Agency
Western Ecology Division
Corvallis, Oregon

Tim Kubiak
U.S. Fish and Wildlife Service
Washington, D.C.

D. Phil Larsen
U.S. Environmental Protection Agency
Corvallis, Oregon

John Lyons
Fish and Habitat Research Section
Wisconsin Department of Natural Resources
Monona, Wisconsin

Frank H. McCormick
U.S. Environmental Protection Agency
Cincinnati, Ohio

Steven A. Newhouse
Indiana Department of Environmental Management
Indianapolis, Indiana

James T. Oris
Miami University
Department of Zoology
Oxford, Ohio

Edward T. Rankin
Ohio Environmental Protection Agency
Division of Surface Water
Groveport, Ohio

Thomas P. Simon
U.S. Fish and Wildlife Service
Bloomington, Indiana

Scott A. Sobiech
U.S. Fish and Wildlife Service
Carlsbad, California

Paul M. Stewart
Department of Biological and Environmental Sciences
Troy State University
Troy, Alabama

John Stoddard
U.S. Environmental Protection Agency
Western Ecology Division
Corvallis, Oregon

Roger F. Thoma
Ohio Environmental Protection Agency
Division of Surface Water
Twinsburg, Ohio

Ian Waite
U.S. Geological Survey
Portland, Oregon

Thomas Whittier
Dynamac Corporation
Corvallis, Oregon

Gerould S. Wilhelm
Conservation Design Forum, Inc.
Elmhurst, Illinois

Douglas Wilcox
U.S. Geological Survey
Biological Resources Division
Ann Arbor, Michigan

Contents

Section I

Conceptual Framework

1 Biological Response Signatures: Toward the Detection of Cause-and-Effect and Diagnosis in Environmental Disturbance

Thomas P. Simon

CONTENTS

1.1 INTRODUCTION

Yoder and Rankin (1995a) were the first to coin the term, "biological response signatures." The term is defined as discernable patterns in the response of aquatic community attributes, so that the information is able to discriminate between different stressor types. Unique combinations of biological community characteristics that aid in distinguishing one impact type over another are detected in the biological community data and respond with discrete signatures. In their paper, which described the effects of select environmental disturbances using biological indicators, Yoder and Rankin were able to segregate various impacts into nine categories of disturbance. These response signatures were considered the mechanisms that would assist environmental managers in diagnosing and providing a prognosis on cause and effect. However, as with many tools the practitioners wanted more resolution and the ability to determine chemical-specific impacts.

Suter (1993) critically evaluated the concepts behind ecological health and the index of biotic integrity (IBI). He stated that his paper "does not attack the concept [IBI] but rather the much more limited belief that the best way to use… biosurvey data is to create an index of heterogenous variables [multimetric approach] and claim that it represents ecosystem health." He outlined ten criticisms that serve as the foundation of any good environmental indicator (Herricks and Schaefer, 1985). Among Suter's criticisms of the IBI are ambiguity, eclipsing, arbitrary variance, unreality, *post hoc* justification, unitary response scales, lack of diagnostic results, disconnection from testing and modeling, nonsense results, and improper analogy to other indices. Karr (1993) responded to many of the issues Suter raised, as did Simon and Lyons (1995). However, one question that has remained about multimetric indices is whether they are relevant.

This project began with the need to determine whether the IBI was relevant, and whether the underlying assumption that metrics could be diagnostic tools to determine specific impacts could be used to identify cause and effect. However, as the project progressed, it became increasingly apparent that the relevancy issue should not be limited to only multimetric indices but expanded to include all biological criteria. Biological criteria are ecological benchmarks based on a variety of biological integrity response measures sensitive to human-induced modifications (Davis and Simon, 1995; Simon, 1999). The U.S. Environmental Protection Agency (USEPA) indicated in 1990 that biological criteria are "narrative and numerical expressions that describe the reference [least-impacted] biological integrity of aquatic communities inhabiting waters of a given designated aquatic life use."

Simon (2000) indicated that biological criteria include narrative and numerical expressions; thus in the broadest sense biological criteria can be based upon a variety of indices including diversity indices (Washington, 1984), univariate indices (e.g., Hilsenhoff biotic index [Hilsenhoff, 1982]), floristic quality index (Swink and Wilhelm, 1994), index of well-being (Gammon, 1976), numerous fisheries population and stock assessment indices (Nielsen and Johnson, 1983), and multimetric indices of biological integrity and sustainability (e.g., Karr, 1981; Karr et al., 1986; DeShon, 1995; Stewart et al., 1999; see Davis and Simon, 1995; Simon, 1999; Fore, Chapter 22). The diagnostic capability of multimetric indices has not been demonstrated on a widespread basis, although specific examples exist (Eagleson et al., 1990; Yoder and DeShon, Chapter 3). It is the intention of this book to explore whether biological criteria developed over the last two decades can address the issue of relevancy.

1.1.1 Independent Application and the Weight-of-Evidence Approach

USEPA's policy of independent application (IA) suggests that all environmental data be weighted equally for evaluation. IA is considered controversial since the biological data, which are direct measures of aquatic life-designated uses, can usually only affect management decisions unilaterally. Under the IA policy, biological data can only affect management decisions when both the whole effluent toxicity and water chemistry data indicate that no problem exists; thus, assessments can only cause more stringent environmental management decisions. The problems associated with habitat modification, loss in biological integrity to less desirable levels, and diffuse non-point source impairments are not easily detected and described under IA. However, the Clean Water Act's purpose is to protect and restore the chemical, physical, and biological integrity of the nation's streams and these issues must be addressed (Karr, 1995).

1.1.2 The Three-Legged Stool and Other Landscape Features

USEPA used the analogy of a three-legged stool to support different monitoring approaches; i.e., water quality parameters, whole effluent toxicity testing, and ambient biological surveys. Karr (1993) challenged this concept as too rigid and inadequate to address changing environmental conditions. Instead, he proposed the analogy of a tripod supporting a spotting scope. In order to see a distant object, such as a designated use, the three legs of the tripod must be adjusted to accommodate the terrain, which is the nature of the water resource problem. The concept of the three-legged stool suggests that all environmental data are equal, while Karr's tripod approach selects the best tool for the assessment.

USEPA suggested that it was important for biologists to outfit a "toolbox" of methods and indicators that could be used for evaluating biological integrity of the nation's surface waters. The