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WATERSHED ASSESSMENT AND IN-STREAM MONITORING

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ABSTRACT

This paper provides a brief introduction to fundamental issues for watershed and regional assessments and identifies the needs for physical, chemical, and biological monitoring and research to be designed and integrated to support such assessments. Regional management requires organizing paradigms or conceptual models, and an assessment framework can serve this purpose; risk assessment is used as an example. Spatial scale (watersheds and ecoregions) can also serve as a strong organizing paradigm for management. The role of federal and state monitoring and assessment programs is discussed with examples for biomonitoring. The two classes of biomonitoring methods are discussed: ecological surveys and toxicity testing. Biological criteria can provide an appropriate reference for monitoring and assessment and can establish statistical and ecological (practical) significance. This paper is based on Chapter 5 of Water Environment Federation's new book, *Biomonitoring in the Water Environment*.

KEYWORDS

Biological monitoring, watershed assessment, biological criteria

INTRODUCTION

Ecologists and many natural resource managers recognize that often the environmental hazards or stressses that we currently have to address affect large geographic areas (for example, acid deposition, nonpoint-source pollution, increased global carbon dioxide alteration of hydrologic systems), yet traditional concepts and methods in ecology and assessment are relevant mainly to single sites or small geographic areas. Also, monitoring programs and assessment needs often have not been integrated, and rigorous quantitative assessments have been the exception rather than the norm for large geographic areas. This paper provides a brief introduction to fundamental issues for watershed and regional assessments and identifies the needs for physical, chemical, and biological monitoring and research to be designed and integrated to support such assessments.

Davis and Simon (1995) and Water Environment Federation's (WEF 1997) new book, *Biomonitoring in the Water Environment*, along with the direction set by national and state programs provide overviews and substantial guidance on how to use biological monitoring effectively in water quality programs. Critical issues for biological monitoring include selection and use of reference sites, relationships between laboratory testing and ambient monitoring, and the need for data on chronic and/or episodic stresses. This paper is based on Chapter 5 of *Biomonitoring in the Water Environment* (Hunsaker et al., 1997).

ORGANIZING PARADIGMS

Regional management requires organizing paradigms or conceptual models, and an assessment framework can serve this purpose; risk assessment is used as an example here. Risk assessment supplies society with a quantitative and systematic way to estimate and compare the impacts of human activities on the environment. Beyond regulatory discharge requirements, assessments provide the purpose or context for biomonitoring. Biomonitoring should be designed to support risk assessment as a fundamental component of environmental decision making because the cost of eliminating all environmental effects is impossibly high and regulatory decisions must be made on the basis of incomplete scientific information. Spatial scale can also serve as a strong organizing paradigm for regional management and is compatible with a risk assessment framework. The spatial construct used to characterize aquatic regions for assessment and management could be either watersheds or ecoregions.

DISCLAIMER

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Several ecological paradigms about rivers emerged over the last two decades since Hynes (1975) proposed that the nature of streams is tightly coupled with catchment/watershed characteristics (Cummins et al., 1984). The stream continuum concept provided a template for examining how biotic attributes of rivers change within the longitudinal gradient from headwaters to outlets at the sea (Vannote et al., 1980). More recently the ecotone concept (Holland et al., 1991) elevated interest in the importance of transformations and fluxes of materials that occur within boundaries between functionally interconnected patches that form the riverine landscape. Landscape ecologists seek to better understand the relationships between landscape structure and ecosystem processes at various spatial scales. Hunsaker and Levine (1995) and others developed methods to characterize landscape attributes that influence water quality at various spatial scales. Understanding how scale, both data resolution and geographic extent, influences landscape characterization, and understanding how terrestrial processes affect water quality are critically important for model development and translation of research results from experimental watersheds to management of large drainage basins.

THE ROLE OF FEDERAL AND STATE MONITORING AND ASSESSMENT PROGRAMS

We have not attained the broad objective of the Clean Water Act—to restore and maintain the chemical, physical, and biological integrity of the nation's waters. Three federal programs illustrate how data can be important by providing baseline or background information for state or site-specific planning and water quality permitting: the Watershed Protection Approach (U.S. Environmental Protection Agency, 1993), Environmental Monitoring and Assessment Program (Thornton et al., 1993), and National Water Quality Assessment (Gilliom et al., 1995). These programs also represent the current direction toward regional planning and more holistic or ecologically based monitoring and assessment (Hunsaker et al., 1997). A few state programs are briefly described to give examples of how states can implement the concepts discussed. The implementation of whole basin planning for water quality is illustrated with an example for North Carolina (Creager and Baker, 1991). Each whole-basin management plan has eight major sections:

- An introduction, describing the purpose and format of the plan;
- A general basin description;
- An assessment of the current status of water quality and biological communities in the basin;
- An overview of existing pollutant sources and loads;
- Identification of significant water quality concerns and priority issues in the basin;
- Long-range management goals and general management strategy;
- Recommended total maximum daily loads, waste load allocations (for point sources), load allocation (for nonpoint sources), and management actions; and
- Implementation, enforcement, and monitoring plans.

Some states are establishing biological and water quality criteria based on ecological regions rather than river drainage basins, e.g., Ohio and Arkansas. Ohio is one of three states that has incorporated numeric biological criteria into water quality regulations.

IN-STREAM MONITORING

Biomonitoring methods can be classified into two categories: ecological surveys and toxicity testing. Ecological surveys may use indicator species, assessments based on the composition of biological communities, numerical diversity and indices, or all of these. By making comparisons between affected and control areas, ecological surveys can indicate the condition of a water body exposed to pollutant loadings. Although ecological surveys provide an assessment of water quality which integrates the effects of exposure over time, the expense of biological surveys and the length of time required to perform them are often mentioned as disadvantages. However, Yoder and Rankin (1985) provide strong quantitative data based on their experience in Ohio to counter this impression. Cairns (1990) outlines three steps that are necessary to establish a sound biological monitoring program, and they are paraphrased here.

- Establish baseline conditions for the community or ecosystem (that is, its structural and functional characteristics, including species composition).

- Develop a conceptual model that determines which attributes are most likely to be first affected as a consequence of anthropogenic perturbations or natural cyclical events. This model can be predictive or retrospective.
- Validate or confirm these predictions in the natural system in question or a surrogate thereof (for example, a microcosm, mesocosm, or field enclosure).

Biological criteria can provide an appropriate reference for monitoring and assessment and can establish statistical and ecological (practical) significance (Davis and Simon, 1995). Confounding effects from natural variability of populations are reduced by using an index period for sampling, application of consistent methodology, and relying on community measures reflecting ecologically important attributes (for example, trophic structure and taxa richness). Principles for successful development and implementation of numeric biological criteria are based upon developing a reference condition (Hughes, 1995) from a regional framework (Omernik, 1995), which may include a multiple metric characterization of the aquatic community (Barbour et al., 1995) and a habitat evaluation (Rankin, 1995). Guidelines by Hughes (1995) for developing a reference condition are listed.

1. Define areas of interest on maps.
2. Define water body types, sizes, and classes of interest.
3. Delineate candidate reference catchments
4. Conduct aerial or photographic evaluation
5. Conduct field reconnaissance
6. Subjectively evaluate quality of candidate reference sites
7. Determine number of reference sites desired
8. Evaluate biological condition of candidate reference sites

SUMMARY AND CONCLUSIONS

Karr (1995) states that we have managed water resources as if the biological systems associated were incidental to society. He lists five realities that point to the need for change: the biological components of water resources are in steep decline; the cause of the decline is broader than simple chemical contamination, the primary focus of conventional water quality programs; the legal and regulatory framework in place today cannot respond in a timely manner to these two realities; long-term success in protecting water resources requires careful thought about assessment endpoints, including development of biological criteria; and the quantitative expectations for attributes that constitute biological health or the integrity of a water resource system vary geographically. Biological monitoring is and will be critical in planning and developing regulatory actions to protect our nation's water quality and aquatic ecosystems.

Perhaps the most important message should be that the concepts of watershed management, ecosystem management, biological monitoring, biological criteria, toxicity testing, NPDES permit, and ecological risk assessment are not entirely disjunct; they should play synergistic roles in moving towards the goal of protection and use of our nation's waters and aquatic ecosystems.

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