ECONOMIC VALUE OF BIOLOGICAL INDICATORS IN WATER POLLUTION POLICY

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Abstract. Ecologists and biologists have long recommended the use of biological criteria in assessing water quality and environmental risk because of the additional information supplied by biological data that cannot be provided by chemical sampling alone. Biological monitoring along with chemical sampling of surface waters may lead to more efficient negotiation, easier enforcement of regulations, and more cost-effective pollution controls. Two theoretical economic policy models have been developed to focus on the efficiency gains expected to result from ecological information.

INTRODUCTION

In recent years, the EPA has responded to criticisms of water resource management policies by calling for holistic watershed approaches that consider the value of a healthy ecosystem in addition to values of human health, recreation and business. The value of ecosystem services that will support specified uses over time is explicitly recognized. The Environmental Protection Agency's (EPA) "Watershed Protection Approach" emphasizes that "the pollution and habitat degradation problems now facing society can best be solved by following a basin-wide approach that takes into account the dynamic relationships that sustain natural resources and their beneficial uses" (U.S. EPA, December 1991).

The natural sciences have made significant progress in using biological information to indicate an ecosystem's health. Volumes of research exist on developing biological monitoring programs and selecting appropriate indicators for customized approaches to water quality problems. Biologists continue their efforts to identify new types of indicators and to test the robustness of others. Incorporating this information into the policy and enforcement process, however, remains a challenge for both natural and social sciences.

Starting in 1977 concerns were expressed that the Environmental Protection Agency's monitoring efforts were insufficient (U.S. EPA, 1990). The EPA in 1987 reported that new monitoring efforts were needed to assess the effect of current policies, to support the nonpoint source (NPS) pollution control efforts, and to enhance research (U.S. EPA, September 1990). In response, the Environmental Monitoring and Assessment Program (EMAP) was developed as a national long-term project for assessing the health of the nation's aquatic ecosystems and for publishing support documents to help states implement assessment and monitoring programs under Section 303(c)(2)(B) of the Water Quality Act of 1987 (U.S. EPA, 1990).

A few states such as North Carolina, Ohio, and Vermont have included biological criteria in water quality legislation (U.S. EPA, July 1991), although traditionally, water quality regulation has been characterized by limiting ambient pollutant concentrations and maximum end-of-pipe loadings. The chemical standards in regulations act as a surrogate for true underlying environmental quality but only represent potential harm. Similarly, microeconomic models for policy analysis have used chemical levels as surrogates for environmental quality. Economic models incorporating biological measures have the potential to better reflect a holistic approach to resource management. This paper discusses the economic value of incorporating additional information given by biological indicators into the policy decision-making process.

First, biological indicators are defined, and their importance over chemical sampling alone is discussed. A presentation of the general economic value of indicators in policy making is given with a focus on the applicability to nonpoint source pollution. We then discuss the potential economic gains from using biological information in two economic models. Finally, a conclusion provides a summary of results and discusses plans for future research and empirical analysis.

BIOLOGICAL INDICATORS OF WATER QUALITY

Biological indicators have traditionally taken the form of taxonomic diversity and pollution sensitivity indices used in Rapid Bioassessment Protocols (RBP) to identify changes in population or communities of certain organisms. The RBP, a qualitative tool used to reduce time and costs of monitoring and analysis, is based on the evidence that different species have different tolerances to pollutants. Impairment is evidenced by noting the richness or number of taxa present without taxonomic identification (Rosenberg and Resh, 1993).

The use of toxicological information in the form of biomarkers complements the use of biological indicators in water quality assessment. Biomarkers are defined as "measurements of body fluids, cells, or tissues that indicate in biochemical or cellular terms the presence of contaminants or the magnitude of the host response" (McCarthy and Shugart, 1990). They include anatomical and cytological abnormalities, adaptive biochemical and immunological responses, response of stress proteins, and DNA changes from the effects of pollutants. Due to a shorter response time, biomarkers provide a more accurate indication of the type and source of pollutants than do population or community responses (McCarthy and Shugart, 1990).

Organisms commonly used as indicators of the quality of water resources are benthic macroinvertebrates, algae, and fish. Ohio uses criteria based on fish and macroinvertebrates for NPDES permitting, for stream channel modifications, and for NPS assessment. North Carolina uses narrative biological criteria to classify water bodies. They have included an antidegradation policy which allows them to set more stringent standards if necessary to protect the existing quality of the water body. Vermont includes both narrative and numeric criteria in their statutes.

ECONOMIC VALUE OF BIOLOGICAL INDICATORS

Biological information in water quality assessment is important for many of the same reasons ecologically and economically. Lacking information on immediate and long-term degradation, chemical measures only present a static picture and give no indication of the underlying damages done to the ecosystem. To identify the effected state of the ecosystem, bioindicators integrate the effects of pollutants over spatial and temporal dimensions (McCarthy and Shugart, 1990). Studying biological indicators at different organism levels reveals effects of bioaccumulated and even quickly metabolized contaminants.

Camargo, in a study comparing the results from physicochemical and biological surveys, demonstrated the importance of including biological monitoring in ecological risk assessment. Chemical and physical measurements in a water system receiving trout farm effluents revealed much less severe pollution effects than indicated by biological indicators (Camargo, 1994).

Bioindicators are important for ecological risk assessment and water quality monitoring when several pollutants are present in a water body. Only a relatively small proportion of the interactions between different pollutants are understood. If multiple pollutants are present, biological indicators can be instrumental in identifying the pollutant causing environmental damage (McCarthy and Shugart, 1990).

By integrating the effects of anthropocentric and natural influences, the additional information provided by bioindicators gives a more refined measure of water quality than does chemical sampling alone. While chemical sampling only indicates potential effects of pollution on biological and ecological processes, biological indicators directly measure this effect. They are closely allied to our true underlying conception of environmental quality.

A primary concern of the effects of NPS pollution is the damage done to ecosystem functioning through sedimentation from erosion, eutrophication from nutrient loadings, and habitat degradation leading to increased temperatures among other changes. Relative to point sources, NPS polluters are difficult to regulate because polluters are hard to identify and effects of polluting activities vary greatly geographically. Runoff occurs during uncontrollable weather events. Therefore, due to the intertemporal nature and quick response systems of some indicators, the timing of episodic loadings can be determined. Sessile organisms help to identify polluters by using a reference site such as an upstream position or a site in a characteristically similar stream for comparative purposes (U.S. EPA, September 1990).

Since monitoring efforts are burdensome and expensive for measuring effluent from nonpoint sources, the dynamic nature of biomarkers offers a cost-effective advantage over chemical sampling alone (U.S. EPA, April 1990). Continuous or periodic biological monitoring will gauge the effectiveness of resource management policies allowing for revisions to be made on a timely basis if practices need to be updated.

Biological indicators give a more relevant and accurate picture of underlying ecosystem health than chemical measurements. With the current emphasis on watershed approaches to environmental management, social goals include ecosystem health. The advances made by natural scientists to link ecological functioning to human processes will improve the ability of policy analysts to choose effective and cost-efficient actions.

With better indicators of underlying environmental quality, negotiating groups will be able to focus more precisely on relevant issues for improved debate and reasoning. According to the EPA (April 1990), "implementing biological criteria in water quality standards provides a systematic, structured, and objective process for making decisions about compliance with water quality standards. ...and increases the value of biological data in regulatory programs."

MODIFYING ECONOMIC TOOLS

Choosing efficient regulatory tools and acceptable levels of contamination has always been difficult. Traditional economic models have generally been specified in terms of effluent quantities or ambient pollution concentrations in estimating the economic efficiency of water pollution policies.

Since biological indicators indicate what we truly value in a healthy ecosystem and incorporate the effects of pollutants over space and time, they lead to more accurate measures of environmental quality and are directly related to environmental goals. The chance of incorrectly assessing environmental quality is reduced by using biological indicators. In other words, there will be a smaller variance around true quality from sampling errors.

Two economic approaches are typically used in policy analysis. Cost-benefit analysis attempts to monetize benefits, compliance costs, and physical damages in ranking policy options by the greatest net benefits. Since chemical measures only reflect potential exposure instead of true environmental damages, we hypothesize that bioindicators imply better valuation of benefits and costs leading to economic gains in choosing the efficient level of pollution.

A second approach to economic modeling of pollution policy is to include a sustainability criterion determined independently of the economic model but used in choosing the least-cost policy to achieve the stated goals. Bishop (1993) and Foy (1990) discuss the need for neoclassical economics to develop a criterion for environmental sustainability by using a physical constraint on economic development called the "Safe Minimum Standard" versus a dollar-only based valuation of resources. Therefore, the value of biodiversity and ecosystem health can be explicitly expressed without monetizing them directly. Because biological indicators measure ecosystem quality more accurately than chemical measures, efficiency gains also result from this model. Due to the uncertainty that is resolved by biological information, less stringent standards are needed on average to ensure with a certain probability that the water quality goal will be achieved at a given level. If chemical measurements are used alone, the chance of measurement error increases and more stringent standards have to be set to insure that the safe minimum standard is achieved.

In a policy context, increasing the use of biological criteria will increase the economic efficiency of water pollution regulation. Even though many applications of bioindicators are used as assessment tools, traditional command-and-control approaches are most often used for regulation. To achieve the economic gains, biological information should be directly incorporated into compliance, monitoring, and enforcement but allowing flexibility in polluters' technical options for compliance. This hypothesis will be tested using biological and chemical data on eutrophication from agricultural runoff.

CONCLUSION

Natural scientists are continuing to develop more sophisticated techniques directly applicable to policy issues. The challenge lies in the adoption of these techniques for NPS pollution policy and enforcement. Currently, most agricultural nonpoint source control actions such as the Water Quality Incentive Plans of the U.S. Department of Agriculture and the Conservation Reserve Program are voluntary.

Biological indicator use is viewed as expensive and complicated. As more environmental managers and policy makers accept the use of biological criteria and scientists continue to make progress in determining the ability of organisms to signal significant stresses, numeric biological criteria may be written into state regulations. Showing the economic value of biological criteria will significantly increase the chance for acceptance. Given the current national political climate, establishing more cost-effective policy, especially at the local level, is crucial for environmental agencies.

Immediate plans for research include a case study analyzing the economic efficiency of using algae or macroinvertebrates in the policy decision-making process and in the subsequent requirements of agricultural NPS water pollution control. Through empirical analysis using the models summarized, the economic value can be measured and our hypothesis asserting the existence of economic gains from incorporating biological data into regulatory practices will be tested.

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