Contributed Papers

Biological Integrity and the Goal of Environmental Legislation: Lessons for Conservation Biology

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Abstract: *Passage of environmental legislation often creates a state of euphoria among supporters such that implementation programs are not rigorously evaluated. Endangered species and water resource legislation are two examples of sound environmental legislation with major weaknesses in their implementation. Regulations to implement the U.S. Clean Water Act, for example, emphasize water quality (physical and chemical properties of water) by calling for uniform standards for contaminants rather than the broader goal of improving the quality of water resources. As a result, improvements in the quality of water resource quality have been limited despite massive expenditures. Natural resource agencies' narrow emphasis on harvested and threatened and endangered species has similar consequences. Unless a comprehensive and rigorous definition of the goals of biodiversity legislation is developed and adhered to by regulatory agencies, efforts to implement biodiversity legislation could lead to similar problems. Protection of biodiversity should be considered a subset of the need to protect the biological integrity of natural resource systems and the ecological health of the biosphere. Programs to protect biodiversity should reflect that more holistic goal and include provisions for evaluating success at attaining stated goals and for making midcourse adjustments in programs when resources are not being adequately protected.*

Resumen: *La aprobación de legislación ambiental con frecuencia crea tal estado de euforia entre los seguidores que los programas de implementación se siguen con ménos rigidez. La legislación sobre las especies en peligro y los recursos de agua son dos ejemplos de legislación con bases ambientales sólidas y con grandes debilidades en su implementación. Las regulaciones para implementar el Acta de Agua Potable de los Estados Unidos, por ejemplo, enfatiza la calidad del agua (propiedades físicas y químicas) haciendo un llamado para uniformizar los estándards de los contaminantes más que la meta más amplia de mejorar la calidad del recurso agua. Como resultado, los mejoramientos en la calidad del agua han sido limitados a pesar de los gastos masivos que se han hecho. El estrecho énfasis de las agencias de los recursos naturales acerca de las especies cosechadas, amenazadas y en peligro tiene consecuencias similares. A menos que se desarrolle una definición comprensiva y rigurosa de las metas de la legislación sobre la biodiversidad y se le adhieran las agencias regulatorias, los esfuerzos para implementar la legislación de la biodiversidad pueden dar lugar a problemas similares. La protección de la biodiversidad debe de ser considerada como parte de la necesidad de proteger la integridad biologica del sistema de recursos naturales y la salud ecológica de la biosfera. Los programas para proteger la biodiversidad deben reflejar esta meta más comprensiva e incluir previsiones para evaluar el éxito al ir alcanzando las metas enunciadas y crear mecanismos para hacer ajustes sobre la marcha en los programas cuando los recursos no estén siendo protegidos adecuadamente.*

Introduction

Just as biological systems are being fragmented by diverse human activities throughout the world, the environmental legislation of the past two decades is a fragmented approach to a broad range of problems. Most environmental legislation and regulations in support of legislation are reactive (damage control) rather than proactive; problems are treated only after degradation is obvious. In addition, duplicate or competitive programs result from the fragmentation of responsibilities among agencies. A recent addition to the legal landscape is a biodiversity bill, an effort to establish a comprehensive United States policy on biological diversity. This legislation comes on the heels of a major review of U.S. programs in biological conservation by the Office of Technology Assessment (OTA 1987). Major goals of the legislation include development of a national policy on biodiversity conservation and a federal strategy to maintain biodiversity, creation of a National Center for Biological Diversity and Conservation Research, and evaluation of project impacts on biological diversity when environmental impact statements are prepared.

Passage of biodiversity legislation would be a major environmental landmark. But as is so often the case, the program to implement that legislation may be more important in determining the success of the law than its explicit provisions will be. Regulations to implement a new law may be inadequate because of ambiguities in the law or in judicial interpretations, or because agency efforts to draft regulations are inappropriate. Effective implementation depends upon clear and concise definition of goals and proper choice of indexes to measure environmental health. The latter must be based on rigorous application of ecological principles.

Biological diversity can be defined as *"the variety and variability among living organisms and the ecological complexes in which they occur"* (OTA 1987). This definition and recent usage of the term "ecological integrity" (Scheuer 1989), recognizes the importance of biological integrity and ecological health as explicit goals of biodiversity legislation. These terms can be defined as follows:

Biological integrity — "The capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition and functional organization comparable to that of natural habitat of the region" (Karr & Dudley 1981).

Ecological health — "A biological system — whether it is a human system or a stream ecosystem — can be considered healthy when its inherent potential is realized, its condition is [relatively] stable, its capacity for self-repair when perturbed is preserved, and minimal external support for management is needed" (Karr et al. 1986).

Unfortunately, these concepts are not central to implementation programs in many environmental situations. Examples of this problem include soil erosion programs initiated in the Dust Bowl of the 1930s, which evolved to focus primarily on enhancing crop production; endangered species legislation that bogged down in a bureaucratic listing process; and water resource legislation that concentrated on control of point sources of pollution through construction of wastewater treatment plants. In this paper, I illustrate potential problems with the implementation of biodiversity legislation using examples from my experience with other environmental legislation — the Endangered Species Act (ESA) and Clean Water Act (CWA).

Endangered Species Act

Endangered species legislation at state and federal levels and through international treaties and conventions has been instrumental in protecting species, in part because it provides easily defined biological goals. By protecting species threatened with extinction, ESA extends legal rights to nonhuman species for their own sake, a clear expansion of the ethical landscape in western culture. Regrettably, that legislation is not sufficient for exactly the same reason — narrowly defined goals centered on endangered species do not protect species from human impacts until their populations are reduced to the point that they are endangered. Further, projects that endanger whole ecosystems are not subject to review, except in special cases, such as when wetlands are affected.

Individuals concerned about endangered species are heartened by recent advances in the implementation of that legislation: (1) expansion of endangered species concerns beyond warm cuddly creatures to include cold-blooded vertebrates, invertebrates, and plants whose populations are in jeopardy, and (2) increased emphasis on "critical habitat" protection. Both strengthen the protection afforded to endangered species.

On the other hand, implementation of endangered species legislation has created a bureaucratic quagmire that diverts attention from larger goals. To some extent, that quagmire derives from the use of esthetic and moral arguments to support the existence of endangered species programs (the warm cuddly issue noted above). While those arguments are not inappropriate, one could argue that they are not sufficient, because many persons do not share concern for fellow travellers on spaceship Earth (Karr 1990*b*).

Often, protection of endangered species is viewed as an obstruction to progress rather than part of an overall strategy to protect Earth's biological integrity. In projects like the Tellico Dam (snail darter), logging of Northwest old-growth forest (spotted owl), and astronomical development on Mt. Graham in Arizona (Mt. Graham red squirrel), ESA goals confront major projects of public concern. Plans to build over a dozen astronomical facilities on Mt. Graham met resistance on several environmental grounds, including the presence of the red squirrel (*Tamiasciurus hudsonicus grahamensis*), a unique, insular subspecies recognized by the U.S. Fish and Wildlife Service as an endangered species. A number of other species and subspecies may warrant similar recognition (U.S. Forest Service 1988). The University of Arizona, however, used political muscle to solicit the aid of the Arizona congressional delegation to push through an exception for the first phase of astronomical development. The action, passed as an attachment to unrelated legislation, circumvented both the National Environmental Policy Act and the Endangered Species Act. In recent action, a U.S. District Court judge temporarily banned observatory construction pending a review of the project's impact.

That endangered species legislation and the regulations used to implement it have evolved is a positive step. The responsibility of practicing conservation biologists, however, must be to ensure that such evolution proceeds rapidly. Robust biological insight must be incorporated into the planning process at the earliest possible stage.

Clean Water Act

The first major legislation designed to protect water resources was passed nearly 100 years ago in 1899 (Karr, 1991*b*). Since then, a series of water pollution control acts have expanded the federal government's role in maintaining water quality, with particular emphasis on funds for constructing wastewater treatment facilities, developing technologies to improve those facilities, expanding lists of pollutants to be regulated, and increasing enforcement to control point sources of pollution.

Major advances were made in controlling domestic effluents, but a growing array of toxic materials produced by human society and the pervasive, more-difficult-to-control non–point sources (diffuse runoff from urban, agricultural, and forest lands) remained largely untreated. Atmospheric deposition of toxic materials is yet another problem that has not been adequately addressed that threatens both terrestrial and aquatic environments. The magnitude of the degradation over the past century is illustrated by data from the Illinois and Maumee rivers, where 66 percent and 43 percent, respectively, of resident fish faunas have experienced major population declines or been extirpated (Karr et al. 1985*b*). As is so often true, no single factor is responsible for this degradation. The primary culprits in the Illinois and Maumee were agriculture, impoundments and levees, navigation, toxics, consumption of water, and introduction of exotics.

This breadth of factors illustrates the folly of trying to restore water resources with single-minded approaches, the dominant theme of agencies dealing with the nation's waters. Environmental agencies often have a primary focus on control of point sources of chemical pollutants through construction of wastewater treatment plants, whereas conservation departments deal primarily with physical habitat degradation in fishable streams. (Paradoxically, wholesale introduction of exotics by those same agencies often tears the fabric of native ecosystems.) In recent years, programs to protect minimum critical flows have gained considerable attention. All treat serious water resource problems but none is sufficient alone.

As a result, the biological integrity of water resources continues to decline in most areas. A few exceptions exist (e.g., Lake Washington near Seattle (NAS 1986), where a single stress, eutrophication, was identified and controlled by a creative interaction of science and political will). More commonly, however, water engineers or planners do not acknowledge the existence, let alone the importance, of the biological communities associated with water resources. Thus, the quality of water resources has not been protected because the primary regulatory approach concentrates on water quality (or water quantity in some western areas) rather than the quality of the water resource. A major lesson emerges from three decades of water resource law and regulations for its implementation — ***environmental legislation must be both well conceived and carefully implemented through sound regulations.***

Perhaps the clearest call for attention to Earth's life support system occurs in the Water Quality Act Amendments of 1972 (PL 92-500) and later revisions of that Act with the mandate "to restore and maintain the physical, chemical, and biological integrity of the Nation's waters." The inclusion of biological integrity was thoughtful (Ballentine & Guaraia 1977), but no provisions were made to define that goal precisely and develop integrative ways to measure successful attainment of that goal. A simple surrogate for biological integrity, water chemistry, was used to evaluate the degradation that stimulated the passage of the Clean Water Act (Karr & Dudley 1981; Karr 1987). As a result, expensive treatment plants were built with relatively little or no effort to measure their impact on the quality of the water resource. In one study (Karr et al. 1985*a*), biotic integrity was degraded by the chlorine added in secondary treatment, and addition of a territory denitrification plant did not improve biotic integrity. Simply put, if water resources are to be protected, a quantitative, ecologically sophisticated method is needed to monitor the biotic integrity of all waters. No nonbiological techniques exist that can serve as a surrogate for the direct measurement of biological conditions in a stream.

Biologists have intuitively known and agreed with this position for over two decades, and a variety of methodologies for achieving it have been proposed (Worf 1980; Taub 1987; Ford 1989; Fausch et al. 1990; Karr 1990*a*). Laboratory studies of acute toxic effects dominated early work with the goal of establishing criteria for specific pollutants (USEPA 1976), an approach that was challenged by many (Thurston et al. 1979; Levin et al.

1989). Focusing solely on acute toxicity in the laboratory misses chronic effects in the field and the synergistic effects of combinations of chemical pollutants. Field monitoring of selected (indicator) taxa was also tried using fish, benthic invertebrates, and diatoms, but by focusing exclusively on assessing the presence of pollution-tolerant forms, researchers miss the opportunity to evaluate other aspects of biotic integrity such as individual health, sizes of populations of component species, and the trophic structure of the community. Because limits to the biological integrity of a water resource vary in space and time, no single approach can be expected to detect and reverse all degradation. To protect water resources, five sets of variables (Fig. 1) that may be affected by human action must be evaluated, and the factor or combination of factors that is responsible for degradation must be treated (Karr et al. 1986).

The need for a more integrative approach to evaluate this diversity of human impacts stimulated the development of an index (Karr 1981; Karr et al. 1986) to assess biological conditions in a river or stream using fish communities. It is called the Index of Biotic Integrity (IBI). This multiparameter index uses attributes of fish communities to evaluate human effects on a stream and its watershed. Use of IBI in both research and regulatory contexts (Karr et al. 1986; Hughes & Gammon 1987; Karr et al. 1987; Hirsch et al. 1988; Hite 1988; Miller et al. 1988; Steedman 1988; Ohio EPA 1988; Plafkin et al. 1989) has spread throughout North America and even to Europe. IBI has been used to evaluate chemical and habitat degradation affecting both in-stream and watershed-level activities. Further, the conceptual framework of the fish IBI has been adopted by benthic biologists in efforts to develop robust methods to measure degradation by monitoring invertebrate communities (Ohio EPA 1988; Plafkin et al. 1989). Ecologically sophisticated biological monitoring is now widely recognized as an essential part of monitoring programs. No other approach provides direct, integrative information about biological conditions at a sample site. The advantages of rigorous analysis of biotic integrity are widely recognized, as are the disadvantages of lack of biotic assessment (Ohio EPA 1988; Plafkin et al. 1989; USEPA 1987, 1988, 1989).

The IBI was conceived to provide a broadly based and ecologically sound tool to evaluate biological conditions in a stream. A single sample from a stream reach is evaluated using 12 metrics (Table 1) to determine the extent to which the resident community diverges from that expected of an undisturbed site in the same geographic area and of the same stream size. Unlike efforts to define chemical criteria that do not take variation by geographic region into account, this approach explicitly recognizes natural variation in water resource conditions. The twelve metrics are grouped into three classes that evaluate the extent to which the fish community has reduced species richness and/or altered species composition, the trophic composition is altered due to human effects on the energy base and trophic dynamics of the resident biota, and the abundance and condition of fish within the community are affected by humans. The IBI can be used to assess local conditions or to evaluate a basin through a number of samples within a watershed (Steedman 1988). Similarly, simultaneous samples at a series of sites can be used to compare areas or multiple samples from a single site can be used to evaluate trends over time (Karr et al. 1986; Hughes & Larsen 1988). Finally, when degradation is detected, judicious use of the IBI can provide information about the factors responsible for degradation.

Monitoring and assessment efforts using the conceptual approach of IBI are more likely to protect the quality of water resources than are more conventional programs that ignore or limit the use of direct biological assessments because the IBI incorporates all the stressors shown in Figure 1.

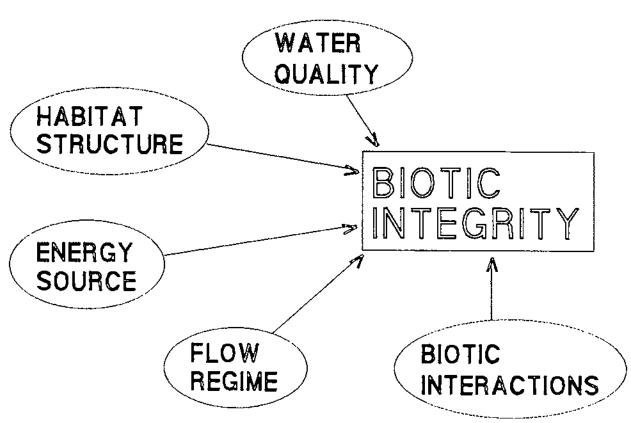

Figure 1. Five major classes of environmental factors that affect the integrity of an aquatic biota.

Discussion

Environmental legislation inevitably has narrow, specific goals, although an umbrella goal that motivates virtually all environmental legislation is the protection of biological integrity and ecological health. It is essential that framers of legislation and those responsible for implementing legislation keep both these issues in mind. Congressional testimony on the 1972 Water Quality Act convinces even the skeptical reader that some advocates of that bill had similar insights. History, however, shows that the larger umbrella was lost with the development of regulations and water resource programs (Anonymous 1981*a*, *b*, 1983). Some published material on biodiversity protection and recent discussion at meetings reinforce my concern about the need to avoid

Table 1. Metrics used to assess fish communities in the midwestern United States (modified from Karr 1981 and Fausch et al. 1984).

Category	Metric[a]	Scoring criteria[b] 5	3	1
Species richness and composition	1. Total number of fish species	Expectations for metrics 1–5 vary with stream size and region.		
	2. Number and identity of darter species			
	3. Number and identity of sunfish species			
	4. Number and identity of sucker species			
	5. Number and identity of intolerant species			
	6. Proportion of individuals as green sunfish	<5%	5–20%	>20%
Trophic composition	7. Proportion of individuals as omnivores[c]	<20%	20–45%	>45%
	8. Proportion of individuals as insectivorous cyprinids	>45%	45–20%	<20%
	9. Proportion of individuals as piscivores (top carnivores)	>5%	5–1%	<1%
Fish abundance and condition	10. Number of individuals in sample	Expectations for metric 10 vary with stream size and other factors.		
	11. Proportion of individuals as hybrids	0%	>0–1%	>1%
	12. Proportion of individuals with disease, fin damage, and skeletal anomalies	0–2%	>2–5%	>5%

[a] *Tabulated metrics are for the original IBI developed in the Midwest. More general metrics applicable outside the Midwest include the following: Metric 1—Native fish species, 2—Benthic species, 3—Water-column species, 4—Long-lived species, 6—Tolerant species, 8—Proportion insectivores, 11—Proportion exotics (see Miller et al. 1988).*
[b] *Ratings of 5, 3, and 1 are assigned to each metric according to whether its value approximates, deviates somewhat from, or deviates strongly from the value expected at a comparable site that is relatively undisturbed.*
[c] *Omnivores are defined here as species with diets composed of ≥25% plant material and ≥25% animal material.*

a narrowing of perspective with respect to the biodiversity bill. Biodiversity, for example, has been defined as "the *elements* of the biosphere" in contrast to ecological processes, "the *interactions* among species and between species and their environments" (Reid & Miller 1989). What if the framers of biodiversity regulations err in focusing only on the former?

Neither protection of endangered species nor the maintenance of clean water will assure that biological integrity and ecological health are protected. Similarly, neither cataloging biological diversity through a national biological inventory nor protecting fragments of natural ecosystems will assure that biological integrity and ecological health will be preserved under biodiversity legislation. Conservation biologists must guard against the allocation of resources to aspects of the biodiversity problem that are too limited or to the development of measuring devices that are too narrow to protect the larger fabric of biological integrity and ecological health. The biodiversity bill must be interpreted as a mandate to protect genes within populations, populations within species, species within communities, communities/ecosystems within landscapes, and landscapes within the biosphere.

Four other problems must be dealt with if biodiversity legislation is to attain its potential. (1) Environmental protection should not be held hostage to political maneuvering (as happened in the case of telescopes versus squirrels on Mt. Graham). (2) Jurisdictional disputes often break out between state and federal authorities and among agencies. These may involve defense of territory or efforts to avoid responsibility. For many years, I heard USEPA officials say that protecting biotic integrity was not their mandate and then cite the implementation regulations of the CWA. (3) Many do not recognize the biological foundations of most environmental problems. (4) Finally, a move away from the ethical, theological, political, economic, and management perspectives that place human life and products above the "less useful" nonhuman life would aid attainment of biodiversity goals.

The disciplines of conservation biology and ecology are at a major threshold. Never before have the challenges and the opportunities been greater and the consequences of inaction more severe. Throughout history, the human-environment interaction has generally been significant only at relatively small spatial and temporal scales. Disease, acts of predation, and accidents were the major decimating factors. Because of population growth and the expanding influence of technology, man's interactions with his environment have shifted such that we face a growing array of difficult challenges, including many that we have not evolved to deal with (Orenstein & Ehrlich 1989). The very difficult problems created by global warming are examples of the consequences of our actions.

Mankind's principal interaction with his environment is no longer at the scale of individuals, and mankind's normal solutions, medicine and technology, can no longer be viewed as panaceas to resolve the ills of modern society. Our biological problems are no longer centered on the health of the individual. Rather, because of our actions, the health of the biosphere is threatened, and we need a new generation of "medicine" men. They should be people with ecological background, trained "physicians of the environment." Like medical pathologists, environmental pathologists must have knowledge of ecologically healthy as well as degraded biological communities if their prescriptions are to be taken seriously.

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