Biodiversity and Management of Natural Resources: *The Issues*

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Introduction

This article characterizes biodiversity, describes the extent and causes of its decline, and considers the likely ramifications of biodiversity issues for fisheries management. We introduce the issues but do not advocate any particular policies.

Clearly, biodiversity has now become a priority in the scientific community and in public policy (Roberts 1990; Lubchenco et al. 1991). Examples include issues of old-growth forests, endangered Pacific salmon stocks (Nehlsen et al. 1991), and the policy of no net loss of wetlands. Issues that we will discuss apply to fisheries, forests, wildlife, and wetlands management.

When the National Academy of Sciences and the Smithsonian Institution conducted a national satellite-hookup conference on biodiversity in 1986, thousands of people participated. The Academy published a proceedings of this symposium (Wilson 1988) that has become popular. The Environmental Protection Agency's Science Advisory Board recently listed loss of biological diversity as one of the four highest risks to natural ecology and human welfare (USEPA 1990). Biodiversity is a public policy as well as a scientific issue and will be increasingly affecting all of us involved with biological resource management.

Scientists are concerned about depletion of biodiversity not only because it has become a popular issue. Fisheries professionals recognize the difficulty in precisely defining biodiversity in a functional sense as well as in defining the linkages between biodiversity and long-term stability of ecosystems. Ecological theory holds that biodiversity maintains ecosystem stability (Odum 1972; Franklin et al. 1989), although this theory has been questioned (Powers 1989). Because the American public has expressed its wishes for protecting biodiversity through legislation such as the Endangered Species Act (ESA), natural resource managers have a legal obligation to address values of biological diversity along with utilitarian, economic, and other biotic resource values.

Background

Although biological diversity has recently become publicly visible, scientists have been interested in protecting the diversity of life for years (Marsh 1864). There is an extensive body of scientific literature on diversity, diversity indices, and the structural and functional stability associated with aquatic ecosystem diversity (Karr et al. 1986; Hughes and Noss 1992, this issue).

In the 1960s, there was widespread public and scientific concern over the loss of "charismatic megafauna" – large, warm-blooded animals such as tigers, pandas, primates, and elephants. In the 1970s, the U.S. Congress enacted the ESA and the Marine Mammal Protection Act. Some people were concerned with such organisms as plants, butterflies, and amphibians, but most were concerned with the highly visible species. In 1980, the term biological diversity began to be commonly used (Lovejoy 1980). During the 1980s, public interest evolved into protecting large ecosystems such as tropical rain forests, the Florida Everglades, Alaskan wilderness, temperate forests of North America, and particularly the old-growth forests of the Pacific Northwest. Species and habitat protection dominated the biodiversity issue throughout the 1980s and the first comprehensive legislative recognition of biodiversity occurred when the U.S. Congress passed the International Environmental Protection Act in 1983. Blockstein (1992, this issue) discusses contemporary legislative efforts to protect biodiversity.

Biodiversity: What Is It?

Definitions of biological diversity tend to be general. For example, McNeely (1988) defined it as "the degree of nature's variety." It has also been defined as "the variety of life and its processes" (Hughes and Noss 1992) and as "the variety and variability among living organisms and the ecological complexes in which they occur" (OTA 1987). Because of the breadth of diversity manifested in the ecological hierarchy, definitions are necessarily general.

Biodiversity can be recognized at four levels in a biological hierarchy (Noss 1983; Norse et al. 1986; OTA 1987): (1) genetic diversity refers to the sum total of information in the genes of individual organisms of a species; (2) species diversity is the number and frequency of organisms in a given area, such as the area occupied by a biological community; (3) ecosystem diversity is related to the variety of ecological processes, communities, and habitats within a region; and (4) landscape diversity is the spatial heterogeneity of the various land uses and ecosystems within a larger region measuring from 100 to 10,000,000 km'.

Increasingly, scientists see biodiversity loss at other than the species level (Norse et al. 1986; Noss 1986). Species extinction can result from the total loss of genetic and population biodiversity. Conversely, biodiversity decreases with increasing species extinction so that species extinction causes loss of genetic and population diversity. Moving up the ecological hierarchy, loss of species diversity may affect ecosystem or landscape diversity.

Many individuals have questioned the ways in which the ESA has been employed (Meese 1989). Species loss continues to be high. Wilson (1988) has estimated a modern extinction rate of 1,000-10,000 species annually, compared with an annual background rate of one species, which would be the highest rate since the mass extinctions of 65 million years ago (Raup 1986). Although most extinctions are in tropical countries, the ESA has provisions intended to extend its protection outside the United States.

Aquatic Biodiversity: Causes of its Decline

Principal causes behind the recent increase in loss of aquatic biodiversity include habitat alteration, fragmentation, and simplification. Physical habitat is altered by channelization, construction of dams and reservoirs, siltation, and degradation of wetlands. Other forces of change include: (1) diversion for irrigation, flood control, and municipal and industrial water use; (2) point source and nonpoint source pollution; (3) acid precipitation; (4) introduction of exotic species; (5) intentional or incidental over harvesting; and (6) interaction among two or more of these stressors (Williams et al. 1989; Nehlsen et al. 1991). Now, we may add (1) the stress of global atmospheric change in the form of the greenhouse effect, and (2) increased ultraviolet radiation because of depletion of the ozone layer.

Some scientists maintain that the ultimate cause of the loss of aquatic (as well as terrestrial) biodiversity is the size of the human population and the ability of each individual to consume increasingly more of the earth's natural resources (Ehrlich and Holdren 1971; Schweitzer 1992, this issue).

Traditional natural resources management tends to reduce diversity through simplification, fragmentation, and selective destruction (Norse 1990). Management works toward the immediate benefit of a few desirable species-rainbow trout and elk, for example-which contributes to a loss of biodiversity. Increasingly, however, the public is placing more value on experiencing pristine nature. When different segments of the public place competing demands on nature, conflicts are inevitable and often contentious.

Biodiversity: What Are Its Values?

The public and the scientific community place a high value on the preservation of biological diversity because of its commercial and ecological importance. Products such as food, fiber, industrial compounds, fuels, and drugs are presently obtained from a relatively few species, but new crops, new medicines, and new industrial products are regularly discovered (Nations 1988). For example, approximately 119 pure chemical substances extracted from higher plants are now used in medicine (Farnsworth 1988). Perhaps these products could be obtained from a simplified and less diverse biosphere, but the potential to discover new medically-useful compounds would be reduced. Moreover, many important agricultural crops depend on wild germ plasma for broadening their genetic bases, maintaining yields, and enhancing capacity to resist insects and pathogens (Spears 1988). The future option value of saving the vast storehouse of genetic material may be the highest value of biodiversity. Thus, many advocate preservation of genetic diversity to maintain options for long-term sustainability of agricultural and aquacultural production (Rick 1974; Iltis 1988; Nehlsen et al. 1991).

Ecological services, such as air and water purification, soil formation and protection, carbon sequestration, re-charging groundwater, protecting watersheds, and buffering floods and droughts are important values of biodiversity (Ehrlich and Mooney 1983). Some maintain that these free ecosystem services, without which present society could not persist, comprise the most important anthropocentric reason to preserve biodiversity (Ehrlich and Ehrlich 1981).

Some have argued that biodiversity must be preserved regardless of any present or future material values to humankind because of species' inherent right to exist (Ehrenfeld 1978). Paul and Anne Ehrlich (1981) discuss the compassion, aesthetics, fascination, and ethics of preserving species richness. Some philosophers say that species have moral value of their own, are valuable in themselves, and their value is not dependent on any uses to which humans put them (Taylor 1986).

The answer to the question "what are the values in biodiversity" is often one of values, morals, and competing rights (Rolston 1985). The concept of biodiversity embraces scientific and human values.

To resolve management issues, society must adopt a common philosophy regarding what values of biodiversity, if any, it wishes to preserve. This common philosophy will have to address the public's desire for mutually exclusive values from natural resources. Perhaps a variety of motivations within society will eventually lead toward a common view that biodiversity is worth preserving.

The distribution of benefits-the equity issue-is central in all public choices. Traditional economic market forces do not adequately address biodiversity issues in terms of equity (McNeely 1988). Often, those who benefit from exploiting the biosphere do not pay the full costs to society, including not only present but future costs (intergenerational equity).

How can we separate anthropogenic ethical values from the science associated with biodiversity? Do we need to separate them? Regardless of individual reasons for valuing biodiversity, science can identify ecological values of diversity at a conceptual level. As environmental scientists, then, we have a challenge to answer the difficult questions surrounding the earth's remaining biodiversity.

Aquatic Biodiversity: Future Considerations

The 1990s will see a greater focus on the biodiversity of aquatic systems. Legislation, such as the Federal Water Pollution Control Act of 1948, indicates that degradation of water resources has long been recognized as a serious problem. However, until recently the loss of diversity in aquatic ecosystems has received relatively little attention, despite the fact that fish are the oldest, the most diverse, and the largest group of vertebrates; they outnumber all other vertebrate species combined. Fish have existed for 400 million years, compared with 2 million years for humans, 150 million years for birds, and 240 million years for mammals (Raup 1988).

The relative lack of knowledge concerning the loss of aquatic biodiversity is partly due to the remoteness and difficulty of monitoring marine habitats. However, the principal factor responsible for lack of scientific and public awareness may be related to the dichotomy between terrestrial and aquatic species-between large, furry, warm-blooded animals (living on the land with humans) and smaller, cold-blooded, largely unnoticed aquatic organisms (McClanahan 1990). Although small algae and invertebrates account for most aquatic organisms, fish are the best-known species of aquatic organisms. Furthermore, because they exist at or near the top of the food chain, fish can serve as indicators of overall aquatic ecosystem well-being (Karr et al. 1986).

The American Fisheries Society (AFS) lists 364 North American fish taxa (species and subspecies) currently considered either threatened (114), endangered (103), or of special concern (147) (Williams et al. 1989). This group includes approximately one-third of all species of North American fish. Of the 254 taxa in the United States, the federal government lists 73 as threatened or endangered, a very conservative figure (Moyle and Leidy 1992). Forty taxa, including 27 species and 3 genera, of North American fish have become extinct during the past century

(Miller et al. 1989). These figures do not include either strictly marine fish (Upton 1992, this issue) or distinct stocks of anadromous species.

Recently, Nehlsen et al. (1991) listed 214 native, naturally-spawning stocks of Pacific salmon, steelhead, and sea-run cutthroat at risk in Oregon, California, Washington, and Idaho. They also listed 106 major West Coast salmon and steelhead stocks that have become extinct. The authors attribute the stock declines to habitat loss, inadequate water flow and passage opportunities resulting from hydropower and other developments, overfishing, and harmful interactions with hatchery fish.

It is less clear exactly which major environmental concerns will emerge in the 1990s, but the two interconnected themes seem to be biodiversity and sustainability. Many people believe that our natural resources (especially our fisheries, forests, and agricultural lands) are not being managed on a sustainable basis. Upton (1992) discussed the need to conserve natural resources through sustainable development. Further, losses of biological diversity reduce our future options for sustainable biological resource management.

Resource managers' consideration of the loss of biodiversity and sustainable use of natural resources focuses on the management of lands and waters for the future. Public agencies are questioning their missions as concern for biodiversity becomes a priority and competes with traditional goals of production of commodities (in particular, fish, lumber, and food).

Federal agencies involved with natural resources manage public lands in different degrees, if at all. For example, the Environmental Protection Agency and the National Marine Fisheries Service have no land management responsibility, the Bureau of Reclamation has some responsibility, and the Forest Service and Bureau of Land Management manage large tracts of public land. An agency's land management responsibilities often conflict with its interests in conserving biodiversity. Titus (1992, this issue) discussed policy needs for protecting biodiversity, and Schweitzer (1992) examined the role of the U.S. Agency for International Development, a primary player overseas.

Conflicts between biodiversity protection and commodity production are evident in the Forest Service (lumber and grazing vs. biodiversity), Bureau of Land Management (grazing and mining vs. biodiversity), Bureau of Reclamation and Army Corps of Engineers (hydropower dams and recreational reservoirs vs. biodiversity), National Marine Fisheries Service (commerce vs. biodiversity), and Fish and Wildlife Service (sport fish, waterfowl, and mammals vs. biodiversity).

Policy Implications for Management of Natural Resources

What the public wants in terms of balancing commodity production and biodiversity is not clear. Most people say they support protecting species and conserving biodiversity. People rarely advocate driving a species to extinction. Although not a typical example of a biodiversity debate, recollection of the snail darter/Tellico Dam confrontation brings the argument to a level of reality to which we can all relate.

The management options of natural resource agencies have ecological, socioeconomic, cultural, legal, and political constraints. For example, the United States has a system of private ownership of property. Whereas terrestrial re-sources tend to be owned by someone, whether public or private, aquatic resources are usually commonly owned. As a result, we have the classic problem of "the tragedy of the commons" (Hardin 1968); that is, commonly owned resources typically are overexploited. There are exceptions, such as water rights, but in general, economic systems treat aquatic resources as public goods and services without costs. In such situations, beneficiaries of the use of the resources do not pay the true depletion costs of those resources.

We also have a system of competing objectives. What might be in the best interest of the public often is not in the best interest of individuals. Most of us are rational creatures and make decisions based on what we perceive to be our own best interests. Competing objectives of cattle grazing, municipal water supply, and fisheries on our federal lands illustrate this dilemma.

How to handle the winners and the losers is a critical problem in resource management. We have the reality of developed countries in a largely developing world. Poverty is a major cause of habitat and biodiversity loss in developing countries but poverty also results from a loss of biodiversity. Corollaries to the loss of biodiversity, such as low agricultural productivity, siltation of surface waters, overgrazing, depletion of freshwater and nearshore fisheries, desertification, and destruction of watersheds contribute to poverty. Thus, actions taken to alleviate the loss of biodiversity must address the socioeconomic causes of poverty (Schweitzer 1992).

Meanwhile, the developed world exerts great stress on the global environment and biodiversity through intensive activities in the manufacturing, energy, and agriculture sectors.

In the United States, we are faced with the so-called "taking issue"; that is, the taking of property without just compensation. The property protections in the U.S. Constitution sometimes conflict with land-use decisions to protect biodiversity. One possible solution is to install a system of public rent payments to property owners which would ensure long-term protection without public owner-ship. This concept is similar to that of conservation easements. Another solution involves simple acquisition of tracts of lands by the public through negotiated purchases.

We have defined several questions without offering answers to the problem of declining aquatic biodiversity. The magnitude and consequences of the problem are tied so closely to our future welfare that the diligence of scientists and policy-makers is required to provide those answers. If the public choice is to prevent further loss of biodiversity, scientists must provide knowledge necessary to meet this public directive.

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References

Blockstein, D. E. 1992. An aquatic perspective on U.S. biodiversity policy. Fisheries (Bethesda) 17(3): 26-30.

Ehrenfeld, D. 1978. The arrogance of humanism. Oxford University Press, New York.

Ehrlich, P. R., and A. H. Ehrlich. 1981. Extinction: the causes and consequences of the disappearance of species. Random House, New York.

Ehrlich, P. R., and H. A. Mooney. 1983. Extinction, substitution, and ecosystem services. BioScience 33(4):248-254.

Ehrlich, P. R., and J. P. Holdren. 1971. Impact of population growth. Science 171':1212-1217.

Farnsworth, N. R. 1988. Screening plants for new medicines. Pages 83-97 in E. O. Wilson, ed. Biodiversity. National Academy Press, Washington, DC.

Franklin, J. F., D. A. Perry, T. D. Schowalter, M. E. Harmon, A. McKee, and T. A. Spies. 1989. Importance of ecological diversity in maintaining long-term site productivity. Pages 82-97 in D. A. Perry, and seven coeditors. Maintaining the long-term productivity of Pacific Northwest forest ecosystems. Timber Press, Portland, OR.

Hardin, G. 1968. The tragedy of the commons. Science 162:1234-1248.

Hughes, R. M., and R. F. Noss. 1992. Biological diversity and biological integrity: current concerns for lakes and streams. Fisheries (Bethesda) 17(3):11-19.

Iltis, H. H. 1988. Serendipity in the exploration of biodiversity: what good are weedy tomatoes? Pages 98-105 in E. O. Wilson, ed. Biodiversity. National Academy Press, Washington, DC.

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 to its rationale. Illinois Natural History Survey Special Publication No. 5. Champaign, IL.

Lovejoy, T. 1980. A projection of species extinctions. Pages 328-332 in Council on Environmental Quality and U.S. Department of State. The global 2000 report to the president, volume 2, the technical report. U.S. Government Printing Office, Washington, DC.

Lubchenco, J., and fifteen coauthors. 1991. The sustainable biosphere initiative: an ecological research agenda. Ecology 72(2): 371-412.

Marsh, G. P. 1864. Man and nature. John Harvard Library Edition, 1965. Harvard University Press, Cambridge, MA.

McClanahan, T. R. 1990. Are conservationists fish bigots? Bio-Science 40(1):2.

McNeely, J. A. 1988. Economics and biological diversity. Inter-national Union for Conservation of Nature and Natural Resources, Gland, Switzerland.

Meese, G. M. 1989. Saving endangered species. Implementing the Endangered Species Act. Pages 47-62 in G. Mackintosh, ed. Preserving communities & corridors. Defenders of Wildlife, Washington, DC.

Miller, R. R., J. D. Williams, and J. E. Williams. 1989. Extinctions of North American fishes during the past century. Fisheries (Bethesda) 14(6):22-38.

Moyle, P. B., and R. A. Leidy. 1992. Loss of biodiversity in aquatic ecosystems: evidence from fish faunas. Pages 127-169 in P. L. Fiedler, and S. K. Jain, eds. Conservation biology: the theory and practice of nature conservation, preservation, and management. Chapman and Hall, New York.

Nations, J. D. 1988. Deep ecology meets the developing world. Pages 79-82 in E. O. Wilson, ed. Biodiversity. National' Academy Press, Washington, DC.

Nehlsen, W., J. E. Williams, and J. A. Lichatowich. 1991. Pacific salmon at the crossroads: stocks at risk from California, Oregon, Idaho, and Washington. Fisheries (Bethesda) 16(2):4-21.

Norse, E. A. 1990. Ancient forests of the Pacific Northwest. Island Press, Washington, DC.

Norse, E. A., and six coauthors. 1986. Conserving biological diversity in our national forests. The Wilderness Society, Washington, DC.

Noss, R. F. 1983. A regional landscape approach to maintain diversity. BioScience 33:700-706.
1986. Nodes, networks, and MUMs: preserving diversity at all scales. Environmental Management 10(3):299-309.

Odum, E. P. 1972. Ecosystem theory in relation to man. Pages 11-24 in J. A. Wiens, ed. Ecosystem structure and function. Oregon State University Press, Corvallis, OR.

OTA (Office of Technology Assessment). 1987. Technologies to maintain biological diversity. U.S. Government Printing Office, Washington, DC.

Powers, R. F. 1989. Maintaining long-term forest productivity in the Pacific Northwest: defining the issues. Pages 3-16 in D. A. Perry, and seven coeditors. Maintaining the long-term productivity of Pacific Northwest forest ecosystems. Timber Press, Portland, OR.

Raup, D. M. 1986. Biological extinction in earth history. Science 231:1528-1533.

Raup, D. M. 1988. Diversity crises in the geological past. Pages 51-57 in E. O. Wilson, ed. Biodiversity. National Academy Press, Washington, DC.

Rick, C. M. 1974. High soluble-solids content in large-fruited tomato lines derived from a wild green-fruited species. Hilgardia 42(15):492-510.

Roberts, L. 1990. Counting on science at EPA. Science 249:616-618.

Rolston III, H. 1985. Duties to endangered species. BioScience 35(11):718-726.

Schweitzer, J. 1992. Conserving biodiversity in developing countries. Fisheries (Bethesda) 17(3):35-38.

Spears, J. 1988. Containing tropical deforestation: a review of priority areas for technological and policy research. Environment Department Working Paper No. 10. The World Bank, Washington, DC.

Taylor, P. W. 1986. Respect for nature. Princeton University Press, Princeton, NJ.

Titus, T. R. 1992. Biodiversity: the need for a national policy. Fisheries (Bethesda) 17(3):31-34.

Upton, H. 1992. Biodiversity and conservation of the marine environment. Fisheries (Bethesda) 17(3):20-25.

USEPA (U.S. Environmental Protection Agency). 1990. Reducing risk: setting priorities and strategies for environmental protection. SAB-EC-90-021.U.S. Environmental Protection Agency, Washington, DC.

Williams, J. E., and seven coauthors. 1989. Fishes of North America endangered, threatened, or of special concern: 1989. Fisheries (Bethesda) 14(6):2-20.

Wilson, E. O. 1988. Biodiversity. National Academy Press, Washington, DC.

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