What Shall Our Rivers Become in Thirty Years?[1]

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Rivers integrate all that happens across the landscapes they drain. Their biological condition is like a report card on the effects of human activities on every watershed. And the report is not good. North America's degraded rivers reflect damaged landscapes as well as our tendency to undervalue our rivers. Do we want this trend to continue?

Through most of the twentieth century, our efforts to protect water and associated resources were stuck in the nineteenth century under an antiquated law, the 1899 River and Harbors (or Refuse) Act. By 1970 it became obvious to President Richard Nixon, Senator Edmund Muskie, and many others that a new approach was needed. With passage of the 1972 Water Pollution Control Act Amendments (PL 92-500), hope came for change in the form of one explicit, wide-ranging, and visionary statement: "The objective of this Act is to restore and maintain the chemical, physical and biological integrity of the Nation's waters."

Despite the clarity of that mandate, the condition of our water resources continues to decline. To reverse that decline, we must now recognize and respond to four realities.

1. Water resources, especially their biological components, are in steep decline. Native species are declining and exotic species are invading waters throughout the United States. The proportion of aquatic organisms at risk of extinction is considerably higher than that of terrestrial organisms. One-third of the fish, two-thirds of the crayfish, and three-fourths of the freshwater mussels found in North America are classed as rare to extinct; "only" 11–14% of birds, mammals, and reptiles are so labeled.

Fish consumption advisories continue to increase (14% from 1994 to 1995), affecting 45 to 47 states each year. Riparian corridors have been destroyed along most U.S. streams. Throughout North America, commercial fisheries that once produced tons of edible fish for humans have declined—generally by more than 90–95%. Does anyone even remember, for example, that there was a thriving commercial fishery in the Illinois River early this century? Degradation is pervasive, despite a strong mandate in the law and massive expenditures to protect "the physical, chemical, and biological integrity" of the nation's waters.

2. Degradation stems from more than chemical contamination, the primary focus of conventional water-quality programs. A principal reason for this widespread degradation is that water resource managers have incorrectly assumed that monitoring for chemical contaminants would ensure chemical, physical, *and* biological integrity. Yet installing wastewater treatment and collector systems in response to local violation of chemical standards may actually damage or even destroy many miles of stream channels and riparian corridors; the effects on local and

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regional biological integrity can be devastating. Priority lists of chemicals simply do not accurately reflect ecological risks. Point-source pollution controls do not effectively counter damage from nonpoint sources or the cumulative effects of multiple contaminants.

Perhaps more important, the chemical-contaminant approach fails to diagnose or correct water resource problems caused by other human influences. People alter habitat structure by removing woody debris or destroying quiet pools. They disrupt flow patterns with dams and remove organic material from riparian corridors. And they change relationships among species by introducing exotics or overharvesting sport or commercial fishes.

3. Long-term success in protecting water resources means focusing on biological endpoints. Water resources are not simply water; their value to society depends on more than water quality and quantity alone. Humans depend on living waterways for many essential good and services; waters that cannot support healthy biological communities are unlikely to support human society. Therefore, biological endpoints are the most fundamental for assessing environmental quality and charting a course for federal and state programs to protect society's economic and ecological interests.

Furthermore, the status of living systems provides the most direct and most effective measure of the integrity of water. We should track—and we now can track—the condition of aquatic systems as we track the status of local and national economies, using sets of measures much like the index of leading economic indicators. Each measure should be sensitive to important characteristics of living communities, not narrow indicators of commodity production or of threatened and endangered status. Together, such measures make up an ecological yardstick.

One such yardstick is the index of biological integrity (IBI), first developed in 1981 for monitoring water resource condition in midwestern US streams,. Like economic indexes, an IBI consists of multiple measures—called metrics—each describing one aspect of the biological condition of a site. IBIs have been developed for stream fishes or benthic invertebrates throughout the world; others are being developed to assess the condition of wetlands. Terrestrial IBIs using plants, insects, and birds are being studied for application to decommissioned nuclear weapons sites.

Researchers choose particular measures to incorporate into IBIs because those measures reflect specific and predictable responses of organisms to human activities across a landscape. These responses behave somewhat like the dose-response relationships measured by toxicologists. An organism's response to a toxic compound varies with dose; similarly, biological responses at a site reflect the cumulative impacts of disturbance affecting that site. When plotted on a graph, these measured responses give rise to ecological dose-response curves. Considered together, such ecological response curves describe the health of complex ecological systems. They also enable decision makers, resource managers, and citizens to predict the ecological consequences of particular human activities (such as logging, grazing, urbanization, or recreation).

To be useful as metrics in an IBI, the biological responses researchers choose to record should be easy to measure and interpret. They must increase or decrease as human influence increases; they should be sensitive to a range of biological stresses. Most important, they must be able to distinguish between natural and human-caused disturbance.

Four key biological features should be tracked: species (or taxa) richness (number of species), species composition, health of individuals, and food-web structure. Collectively, these attributes detect (1) changes in species, including the identity and number of species present in the regional biota; (2) ecological processes such as nutrient dynamics and energy flow through food webs; and (3) health of individuals, which influences survival and reproduction. Together these features paint a comprehensive picture of water resource condition.

Benthic invertebrates and fish are particularly appropriate for use in an IBI. Invertebrates are abundant and easily sampled, and the species living in virtually any water body represent a diversity of morphological, ecological, and behavioral adaptations to their natural habitat. The species richness, species composition, individual health, and feeding and reproductive relationships of fish and invertebrates shift as humans alter watersheds and water bodies. Those changes, like the changes in temperature or altered blood cell counts in a human, signal "ecological disease."

Samples of invertebrates from one of the best streams in rural King County, Washington, for example, contained 27 kinds (taxa) of invertebrates; similar samples from an urban stream in Seattle contained only 7 taxa. The rural stream has 18 taxa of mayflies, stoneflies, and caddisflies, the urban stream only 2 or 3. When these and other metrics are combined in an index based on invertebrates, the resulting "benthic index of biological integrity (B-IBI) provides a numeric description of the condition, or health, of a stream (Table 1). The B-IBI for the rural stream in King County was 43 (maximum index is 45) and that for the urban stream was 9 (minimum 9).

B-IBI can also be used to compare sites in different areas. For example, nearly pristine areas in Grand Teton National Park have near maximum B-IBIs (Table 1). Streams with moderate levels of recreation in their watersheds had B-IBIs that were not significantly lower, but places where recreation intensity was high were clearly degraded. Urban streams in Jackson, Wyoming, are even more degraded, yet not as bad as urban streams in Seattle. Thus this numeric index makes it possible to compare stream quality across geographic areas so that citizens as well as managers can establish priorities for protection and restoration.

Table 1. Benthic indexes of biological integrity (B-IBI) for streams in King County, Washington, and in and near Grand Teton National Park, Wyoming.

Region	**Land Use**	**B-IBI**
King County, WA	Rural	43
	Urban	9
Grand Teton Region, WY	Little or no human activity	44
	Low to moderate recreation	41
	High recreation	28
	Urban	21

Multimetric biological monitoring recognizes that the quantitative biological conditions that constitute biological integrity (health) vary geographically because the underlying chemical, physical, and biological properties of streams vary regionally. Chemical standards this variation at a high cost to the biota of rivers. Properly used, IBI is calibrated to account for that variation, a point illustrated by the comparison of Puget Sound lowland and Rocky Mountain streams (see Table 1). Historically, biologists tended to measure everything, an approach that is expensive and logistically impossible. It is also unnecessary when a set of biological attributes that reliably reflects biological condition is integrated into an index of biological integrity.

Biological monitoring and assessment ultimately provides objective descriptions of the condition of our waters. They diagnose and identify chemical, physical, and biological impacts as well as their cumulative effects; they can serve many kinds of environmental and regulatory programs when combined with chemical and toxicity testing. And they are cost effective. Most important, because biological monitoring is sensitive to many different impacts of human activity, it is less likely than a solely chemical approach to underprotect water resources.

4. The Clean Water Act establishes a clear objective, and science provides a yardstick, but the regulatory framework and its implementation need to catch up. Neither the prior appropriation doctrine nor the technology-based enforcement of the Clean Water Act over the past 20 years has adequately protected water resources from harmful human actions. Although regulation of point sources of pollution yielded important improvements, the other serious threats (flow alteration, exotics, physical habitat degradation, overharvest, mixtures of chemical pollutants) were not adequately addressed. Compounding the problem, narrow and often non-overlapping charges to federal and state agencies limited their ability to focus effectively on what's really at stake in the degradation of water resources.

And at $473 billion from 1970 through 1989, costs to build operate and administer water-pollution control facilities have been high. Programs to manage National Pollution Discharge Elimination System (NPEDS) permits are expensive and their connection to the condition of rivers is often tangential at best. Underfunding—the chronic complaint of bureaucracies and scientists—is not a barrier to more effective management. Long-term work in Ohio and other states shows that biological evaluations are more cost effective at accomplishing the broad objective defined by the Clean Water Act.

In short, the mandate to restore and maintain the chemical, physical, and biological integrity of the nation's waters is clear, and scientifically sound and cost effective tools for biological monitoring and assessment are now available. We no longer need to implement the Clean Water Act as if crystal-clear, distilled water running down concrete conduits were its objective.

Do we care what our rivers will be like in 30 years? Are we prepared to enter a dialogue to define what we want? Are we prepared to act on the results of that dialogue? As Senator Muskie put it 25 years ago: "Can we afford clean water? Can we afford rivers and lakes and streams and oceans which continue to make life possible on this planet? Can we afford life itself? . . . These questions answer themselves."