Northwest Science Forum

Northwest Science Forum provides an opportunity to articulate and discuss scientific issues in a less structured format than peer-reviewed articles. The Forum publishes short articles, opinion pieces, and letters with a focus on science and natural resource issues in the Pacific Northwest. Although the Forum is not peer-reviewed, it is edited for format and clarity. Articles should generally be less than 2000 words and contain minimal literature citations. Letters in response to articles are particularly encouraged; the original author will normally be given a chance to respond to the letter as well. There are no page charges or reprints associated with the Forum, and participants need not be members of the Northwest Scientific Association. Please send all submissions, including two hard copies and an electronic copy (any recent version of Word or WordPerfect) to the Editor.

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The Future Is Now: Biological Monitoring To Ensure Healthy Waters[1]

"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."

Senator Edmund Muskie, 1972

Aquatic ecosystems embrace an interactive mosaic of environments extending from headwater streams and meadows through mainstem rivers to the sea. This mosaic includes small streams and large rivers, shorelines and streambeds, terrestrial watersheds and groundwater aquifers. Water, plants, animals, nutrients, debris, and byproducts of human society move among these environments no matter what the political boundaries or legal constructs established without regard for the connections.

Because rivers integrate everything in their landscapes, the living organisms found in rivers tell us about the status and quality of their watersheds. Unfortunately, the story told in North America's rivers today is one of damaged landscapes and the historical tendency to undervalue our rivers. Now is the time for citizens and their government agencies to reverse this trend.

Through most of the twentieth century, national efforts to protect water and associated resources were defined by the 1899 Rivers and Harbors (or Refuse) Act, which was passed to control sewage and oil spills in navigable waterways. By 1970 it was obvious that we needed a new approach. With passage of PL 92-500, the 1972 Water Pollution Control Act Amendments (now referred to as the Clean Water Act), hope for change came 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."

Although progress has been made under this law in controlling point-source pollution (as from factories or wastewater treatment plants), other

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[1] This article was excerpted from *Streamkeepers: Aquatic Insects as Biomonitors*, published by the Xerces Society, a conservation organization devoted to invertebrates and the preservation of critical biosystems worldwide. To order a copy of *Streamkeepers*, a book of color photographs and essays about the ecology of rivers, and the potential of aquatic insect monitoring for wild fish and watershed conservation, contact the Xerces Society at 4828 SE Hawthorne Boulevard, Portland, Oregon 97215; phone (503)-232-6639.

harm continues—nonpoint pollution (such as runoff from agricultural, forest, or urban areas); altered hydrological regimes; habitat destruction; and the introduction of exotic species. To break this pattern, we must now recognize and deal with the following facts:

- Water resources, especially their biological components, are in steep decline.
- Degradation stems from more than chemical contamination, yet conventional water-quality programs focus primarily on that one dimension. The biota of rivers offers a multidimensional view and a more effective analytical tool.
- Long-term success in protecting water resources means measuring their condition with biological criteria, that is, by monitoring the organisms (such as insects, fish, or plants) that inhabit our rivers and streams.
- The Clean Water Act establishes a clear objective, and science provides the tools, for protecting our waters, but the regulatory framework and its implementation have yet to catch up.

We must begin to track the condition of aquatic systems the way Wall Street tracks the economy with gauges like the index of leading economic indicators. Our biological index should be sensitive to many different characteristics of living communities, as economic indicators describe many different aspects of economies. A good biological index should be much broader than an indicator of commodity production (e.g., water, fish, shellfish) or a count of threatened and endangered species.

Using biological criteria to monitor and sustainably manage our aquatic resources is a vital necessity in the face of current trends. 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. For example, only 11 to 14 percent of birds, mammals, and reptiles are classed as rare to extinct, but *34 percent of the fish, 65 percent of the crayfish, and 75 percent of the freshwater mussels found in North America are included in that category.*

Fish consumption advisories continue to increase, affecting forty-five to forty-seven states each year. Shoreline, or riparian, corridors have been destroyed along most U.S. streams. Throughout North America, commercial fisheries that once produced tons of edible fish (salmon, bass, shad, etc.) for humans have declined—generally by more than 90 to 95 percent. In the Pacific Northwest, 214 native, naturally spawning Pacific salmon and steelhead stocks face a high or moderate risk of extinction, or are of special concern. Since 1910, naturally spawning salmon runs in the Columbia River have declined by more than 95 percent.

We now know that a principal reason for these widespread losses is landscape alteration; monitoring for chemical contaminants does not identify the consequences of these alterations. Priority lists of chemicals simply do not reflect ecological risks accurately. Point-source pollution controls do not effectively counter damages from nonpoint sources or the cumulative effects of multiple contaminants. Further, installing wastewater treatment and collector systems to comply with chemical standards may actually damage or even destroy many miles of stream channels and riparian corridors; the effects on local and regional biological integrity can be devastating.

The chemical-contaminant approach fails to diagnose or correct water resource problems caused by other human influences. In the process of logging, grazing, urbanization, and recreation, we alter habitat structure by removing woody debris or destroying quiet pools. We disrupt flow patterns with dams or constructed channels. We remove organic material from riparian corridors, and we change relationships among organisms by introducing exotics or overharvesting fish for sport or commerce.

Long-term protection of water resources requires that we focus on the living organisms that inhabit our rivers and streams, because the value of water resources to society comes from more that water quality and quantity. Humans depend on living waterways for many essential goods and services; waters that cannot support healthy biological communities are unlikely to support human society. Biological criteria provide the most effective markers of environmental quality and the most relevant guideposts for federal and state programs to protect society's economic and ecological interests.

One biological gauge is the index of biological integrity (IBI), first developed in 1981 for monitoring midwestern U.S. streams. Like economic indexes, an IBI consists of multiple measures (called metrics), each describing one aspect of a site's biological condition. IBIs have been developed for stream fishes and benthic (bottom-dwelling) invertebrates throughout the world; other IBIs are being developed to assess the condition of wetlands. Terrestrial IBIs using plants, insects, and birds are being tested for use at decommissioned nuclear weapons sites and to measure the health of forest ecosystems.

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 demonstrate ecological dose-response curves. Considered together, they 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 that researchers choose to record should be relatively 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 discriminate human-caused disturbance from the background of natural variability. Historically, biologists tried to measure everything. But in addition to being expensive and logistically impossible, measuring everything fails to focus on clear signals of human-caused degradation.

Key biological features should be tracked to detect changes in species, including the identity and number of species present in standard samples; ecological processes such as nutrient dynamics and energy flow through food webs; and the health of individuals, which influences survival and reproduction. These features provide a comprehensive picture of water resource condition—one that goes beyond the toxicity or extent of chemical pollutants. 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. As humans alter watersheds and water bodies, shifts occur in taxa richness (number of kinds), species composition (identity of species), individual health, and feeding and reproductive relationships of fish and invertebrates.

Samples of invertebrates from one of the best streams in rural King County, Washington, for example, contain twenty-seven taxa of invertebrates; similar samples from an urban stream in Seattle contain only seven. The rural stream has eighteen taxa of mayflies, stoneflies, and caddisflies, the urban stream only two or three. 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 forty-three (the nine-metric index maximum is 45); that for the urban stream was 9 (the index minimum).

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

The 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. Streams with moderate levels of recreation in their watersheds have B-IBIs that are not significantly lower than those without human use, but places where recreation is heavy are clearly damaged. Urban streams in Jackson, Wyoming (near the National Park) 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. Multimetric biological monitoring recognizes that the quantitative biological conditions that constitute health vary geographically because the underlying chemical, physical, and biological properties of streams vary geographically. Properly used, IBI is calibrated to account for that variation.

Biological monitoring and assessment ultimately provide objective descriptions of the condition of our waters. They diagnose and integrate chemical, physical, and biological impacts as well as their cumulative effects; they can serve many kinds of environmental and regulatory programs when integrated with chemical analyses and single-species toxicity testing in the laboratory; and they are cost effective. Most important, because biological monitoring is sensitive to different impacts of human activity, it offers greater protection to water resources than chemical testing alone can provide.

Biological monitoring provides a more economical and effective method for accomplishing the broad objective articulated in the Clean Water Act. We no longer need to implement the act as if crystal clear distilled water running down concrete conduits were its objective. The tools for effective biological monitoring and assessment are now available.

Protecting water quality goes beyond clear water, beyond protecting single desired species. Certain taxa may be valuable for commerce or sport, but these species do not exist in isolation. We cannot predict which organisms are critical to the persistence of commercial species or species we want for other reasons. Failing to protect phytoplankton, zooplankton, insects, higher plants, bacteria, or fungi ignores the key contributions of these taxa to healthy biotic communities. *No matter how important a particular species is to humans, it cannot persist outside the biological context that sustains it.*

Water law that exists today still reflects the needs of a young, uncrowded nation moving into a limitless frontier. One hundred and fifty years ago there was less scientific knowledge, societal values were different, and ample water was available. Times have changed, and our attitudes must too. Only an integrative approach within each level of government (EPA, Forest Service, Fish and Wildlife Service, Geological Survey), across levels of government (local, state, regional, national, international), and among citizen groups can protect water resources.

Perhaps the most important step toward real protection of the nation's waters is to stop talking about water quality and start formulating policy that protects the biological integrity of our rivers, streams, lakes, wetlands, and oceans. Let us adopt a broader concept of water; redefine societal goals based on that concept; forge partnerships among scientists, policymakers, resource managers, and citizens to attain those goals; revise the legal framework guiding water resource policy; and redouble our efforts to protect high quality waters and to restore those that are degraded.