Invited Feature

Maintaining and Restoring the Ecological Integrity of Freshwater Ecosystems: Refining Biological Assessments[1]

Water quality legislation in several countries directs federal, state, or local governments to assess and monitor the biological integrity of surface waters as part of their water quality management programs (e.g., the United States Clean Water Act, the European Union's Water Framework Directive, Australia's Water Reform Framework). Over the past three decades considerable effort has been devoted to the development of indicators for use in these biological assessments. These indicators are typically based on community-level attributes and are designed to assess the degree to which biological communities are different from that expected to occur under reference or baseline conditions (e.g., ⟨www.epa.gov/ost/biocriteria⟩). To the extent that these indicators assess the overall health of entire communities, they are key to understanding and quantifying both the biological impacts of ecosystem alteration and the degree to which management practices are effective in restoring or rehabilitating them.

Effective management of freshwater ecosystems requires two fundamental pieces of information, both of which derive, in whole or part, from biological assessments: (1) What is the biological status of the ecosystem? (i.e., has it been impaired?) and (2) What caused the impairment? Much progress has been made over the last three decades in developing and refining indicators to assess biological status in aquatic ecosystems. Much less work has focused on developing and testing methods that can identify specific causes of impairment. This latter piece of information is critically needed if we are to develop effective restoration strategies. Some of the progress in building the science of bioassessment has involved uncoordinated efforts by different researchers and states in which the focus of work was to develop indicators that *worked* in particular regions and under specific environmental settings. These efforts have improved the technical capabilities of individual states, but they have also contributed to a growing problem of data comparability. Comparisons and summaries of biological conditions across administrative jurisdictions can be difficult if not impossible. We are thus in the awkward situation of having more data than exist for perhaps any other type of ecosystem, but data that were collected with different field methods, and often on different sets of organisms, and data that were summarized into different types and flavors of indicators.

The aim of this Invited Features is to synthesize some of the recent work that has attempted to bring greater conceptual and methodological coherence to the science of bioassessment. Three papers focus on the measurement and interpretation of biological condition. Davies and Jackson offer a conceptual framework that describes how general features of aquatic ecosystems respond to stress. This framework, the *biological-condition gradient*, was designed to provide a way of mapping disparate indicators onto a common scale of biological condition, thus facilitating comparisons among programs and development of consistent biological criteria. Stoddard et al. examine how the concept of "reference condition" has been variously defined and applied within the aquatic bioassessment literature. Given that inferences regarding the condition of a water body depend heavily on how reference, or baseline, states are defined and determined, their plea for more consistent use is especially important if we are to attain comparability among programs and analyses. Hawkins explores how well a single standard indicator might work in quantifying the biological integrity of diverse types of streams both within and across large regions, and thus improve comparability. Hawkins concludes that such a standardized approach has both strengths

[1] Reprints of this 62-page Invited Feature are available for $9.25 each, either as PDF files or as hard copy. Prepayment is required. Order reprints from the Ecological Society of America, Attention: Reprint Department, 1707 H Street, N.W., Suite 400, Washington, D.C. 20006 (esaHQ@esa.org).

and weaknesses and shows that, although most indicators in use are reasonably correlated with one another, they differ in both precision and bias. Hence, our perception of biological condition is to some extent a function of the indicator used. DeZwart et al. conclude the Invited Feature by demonstrating an innovative method for diagnosing the relative importance of different stressors acting on individual ecosystems. Their method merges field-based assessments of species loss (status) with eco-epidemiological modeling to produce data that can then be summarized into easily interpretable graphical output. Such output should be useful to both researchers and decision makers.

The four papers in this Invited Features provide a concise glimpse of the state-of-the-science of freshwater bioassessment. As such, they identify what has been accomplished to date as well as some of the remaining challenges that are in need of attention from the ecological research community. The ideas explored here also have implications that transcend freshwater ecosystems. The large body of knowledge that has developed for aquatic ecosystems should also be of use to those interested in assessing the condition of other, sometimes less studied, types of ecosystems and their biota.

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Key words: bioassessment; conceptual framework; environmental degradation; freshwater; indicators; monitoring; pollution; predictive models; reference condition; restoration; stress.