JOURNAL OF
ECOLOGY AND ENVIRONMENT
http://www.jecoenv.org

Research Paper
J. Ecol. Environ. 36(1): 85-88, 2013

Biological assessment of streams and rivers in U.S. - design, methods, and analysis

Brenda Rashleigh[1,*], Steve Paulson[2], Joe Flotemersch[3], Peg Pelletier[1]

[1]U.S. Environmental Protection Agency, Narragansett, Rhode Island, USA
[2]U.S. Environmental Protection Agency, Corvallis, Oregon, USA
[3]U.S. Environmental Protection Agency, Cincinnati, Ohio, USA

Abstract
Bioassessment is the use of biosurvey data, most commonly for benthic macroinvertebrates and fish, to obtain information about the health of waters in a region. In rivers, bioassessment results are used to evaluate biological condition and trends, to establish relationships between stressors and impairments, and to guide and evaluate management actions.

Keywords: bioassessment, monitoring, macroinvertebrates, fish, multimetric index

INTRODUCTION

Bioassessment is the use of biosurvey data to obtain information about the health of specific bodies of water. Biosurvey may measure the presence, condition, numbers, and types of fish, benthic macroinvertebrates, amphibians, algae, and plants. Biological endpoints provide the advantages of being easy to measure, responsive to stress in the watershed over time; and often ecologically important. Bioassessment is most commonly conducted in rivers and streams; it can also be applied in lakes, wetlands, and estuaries. There are several applications of the results of bioassessment: to evaluate the biological status, condition, and trends for a water body; to distinguish among potential stressors; to establish credible relationships between stressors and impairments; and to guide efforts and evaluate the effectiveness of management actions, including protection and restoration (Barbour et al. 1999). Bioassessment data are most effective when integrated with other measures of stream and river assessment, such as physical habitat, water chemistry, and landscape information (Angradi et al. 2009). We briefly review bioassessment methods, analysis, and some recent developments in both areas.

BIOASSESSMENT METHODS

In the U.S., monitoring is typically conducted by federal and state governmental organizations, as well as non-governmental organizations (NGOs). A set of standardized methods has evolved at the federal level. National-level methods are provided by the U.S. Geological Survey (Moulton et al. 2002), and by the U.S. Environmental Protection Agency (EPA) (Barbour et al. 1999, U.S. EPA 2007). Most U.S. states also collect these data, and have established protocols that are similar to the national protocols. Most common methods for collecting algae include artificial substrates and hand collection (scraping of rocks). Most common methods for macroinvertebrates include collection nets (Slack sampler, kick net) and "grab" samplers. Most common methods for fish include

Open Access http://dx.doi.org/10.5141/ecoenv.2013.010

Received 04 March 2013, **Accepted** 17 March 2013

***Corresponding Author**
E-mail: Rashleigh.Brenda@epa.gov
Tel: + 401-782-3014

ISSN: 2287-8327 (print) ISSN: 2288-1220 (online)

electrofishing or seining. Additional methods have been developed for large rivers (Flotermersch et al. 2006). Seasonality is a consideration for methods development: the life cycles of algae and benthic macroinvertebrates, and the migration of fishes, can influence their distributions. Additional considerations include the sampling of representative habitat, rigorous sample tracking and preservation of samples for future identification, and preservation of archived samples of fish (Barbour et al. 1999).

Monitoring is conducted based on a sampling framework that describes the spatial distribution of sampling locations. In order to generate an unbiased, representative assessment, a randomized design is often used. For large regions, stratification may be used to generate subregions that are more homogeneous. For regional scale frameworks, Frimpong and Angermeier (2010) found that the best approach for stratification by zoogeographic and physiographic units. A challenge in the development of national-level assessment is that some regions are more degraded than others. Herlihy et al. (2008) suggest that region-specific models be developed, which addresses this issue, where reference site quality and assessment thresholds are set by region. However, it makes the comparison across regions more difficult. This could be addressed by assessing these reference conditions against one another. A recent review of monitoring design (Strobl and Robillard 2008) notes that monitoring network designs should consider input from policy and public sectors, as well as scientists and managers, and should be periodically reassessed.

Two future directions in bioassessment include recognizing the role of the stream network in influencing assemblages, and incorporating genetic and molecular techniques into bioassessment. Recent work (Hitt and Angermeier 2011) recognizes the importance of stream network position to bioassessment, where dispersal among streams influences fish community composition over small spatial scales (10 km), and may influence certain metrics often used in bioassessment programs. The development of molecular and genetic techniques is a future direction that is showing promise for early detection of stressor effects on individuals. A recent study by Pilgrim et al. (2011) hypothesized that DNA barcoding could provide greater discriminatory ability than current genus-level identifications of species, which could lead to more specific and sensitive assessments of water bodies, however, their analysis demonstrated limited advantages of this technique.

ANALYSIS

Most water resource agencies in the U.S. use a multimetric approach for the analysis of bioassessment data (e.g., Karr and Chu 1999). A multimetric approach involves two steps: 1) selection and calibration of metrics, which can be combined into a multimetric index, and 2) the assessment and judgement of impairment. The selection of metrics is a well-documented activity (e.g., Barbour et al. 1999, Whittier et al. 2007). Metrics should be tested for performance across the full human disturbance gradient in a region, in order to improve statistical confidence, and to reduce bias (Diamond et al. 2012). A multivariate approach has also been used to analyze bioassessment data. Multivariate statistical analysis of biosurvey data can be used to assess stressor impairment (EPA 2000) and explore patterns in aggregations of taxa or taxon traits (Qian et al. 2012). A popular technique is the generation of the Observed/Expected (O/E) ratio as an indicator for each site – the Observed taxa richness (O) is obtained from the field sampling at a site, and the Expected taxa richness (E) is calculated as the sum of statistically generated probabilities of occurrence for each taxa (Hawkins 2012). Using this approach, a reference site is expected to have an O/E ratio of 1.0; a site impaired by stressors will have a value <1. A similar multivariate approach is used by water resource agencies in Europe and Australia (Wright 2000). Another direction is the use of a Biological Condition Gradient approach, which allows the assessment of directional trends, summary of different methods to a common scale, and easier communication to bioassessment results to non-scientific audiences (Davies and Jackson 2006).

Results from the bioassessment can be summarized at regional and national levels. For example, Paulson et al. (2008) reported that for the first U.S. Wadeable Streams Assessment, data collected at 1392 randomly selected sites yielded the result that 42% of the length of US streams was in poor condition compared to best available reference sites, 25% was in fair condition, and 28% was in good condition. A current challenge is the comparability of different bioassessment programs, Cao and Hawkins (2011) provided several recommendations for improving how different bioassessment programs can be integrated. Hughes and Peck (2008) describe the challenges of reaching a compromise between scientific rigor, consistent and practical implementation over large regions and many participants, and the realities of time and money; they emphasize the importance of advance planning, standardized methods, and cooperative research.

ACKNOWLEDGEMENTS

This is ORD tracking number ORD-003923 of the Atlantic Ecology Division, National Health and Environmental Effects Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency. Although the research described in this article has been funded by the U.S. Environmental Protection Agency, it has not been subjected to Agency review. Therefore, it does not necessarily reflect the views of the Agency.

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