

The Ontario Benthos Biomonitoring Network

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Abstract

The Ontario Ministry of the Environment and Environment Canada (Ecological Monitoring and Assessment Network – EMAN) have established a partnership to develop an aquatic, macro-invertebrate biomonitoring network for lakes, streams, and wetlands. The resultant Ontario Benthos Biomonitoring Network (OBBN) provides a framework for evaluating aquatic ecosystem condition using shallow-water benthos and the reference-condition approach. The OBBN is being developed on the principles of partnership, free data sharing, and standardization. The OBBN protocol outlines field, laboratory, and data-interpretation options which: 1) ensure standardization with proposed federal protocols; and 2), permit partners with varying financial and technical resources to participate. Biological criteria for evaluating aquatic ecosystem condition are generally not available. The OBBN uses a reference-condition approach to bioassessment in which samples from minimally impacted (or reference) sites are used to define the normal range of variation for a variety of indices that summarize biological community composition. Sites where biological health is in question can be evaluated by determining whether test site indices fall within the normal range established from the minimally impacted sites. The OBBN will remove barriers to the application of aquatic biomonitoring techniques across Ontario by specifying standard methods, enabling data sharing between partners, automating analysis using a reference-condition approach, and providing training. EMAN sees the OBBN as a pilot project for a Canada-wide aquatic biomonitoring program.

Introduction

The Ontario Ministry of the Environment (MOE) and Environment Canada (*Ecological Monitoring and Assessment Network* [EMAN]) are co-founders of the *Ontario Benthos Biomonitoring Network* (OBBN). The OBBN will allow partners to evaluate aquatic ecosystem condition using the reference-condition approach and shallow-water benthos as indicators of environmental quality. We are developing the OBBN on the principles of partnership, free data sharing, and standardization. The network's protocol outlines field, laboratory, and data-interpretation options, which ensure standardization with proposed federal protocols and provide enough flexibility that partners with varying financial and technical resources can participate. This paper outlines the importance of biomonitoring, explains what benthos are and why they are frequently used as indicators of aquatic ecosystem condition, describes OBBN components, discusses how participating in the OBBN would benefit Ontario Parks, and lists several research questions related to the development of the network.

Importance of Aquatic Biomonitoring

Monitoring supports adaptive water management; it provides feedback on the status of aquatic resources and the performance of policies, programs, and legislation (Executive Resource Group, 2001). Biomonitoring — the process of sampling, evaluating, and reporting on ecosystem condition using biological indicators (Rosenberg and Resh, 1996a) — is an important part of aquatic ecosystem management. This is because management end-points are often biological (e.g., protection of aquatic biota and their habitats), and because Ontario laws and policies stress the protection of aquatic biota.

Ontario's legislative basis for biomonitoring includes the Ontario *Water Resources Act*, which states that:

“the quality of water shall be deemed ... impaired if ... the material discharged ... causes or may cause injury to any person, animal, bird or other living thing ...” (Government of Ontario, 1990a).

It also includes the *Environmental Protection Act*, which has several biological components in its definition of adverse impact:

“(a) impairment of the quality of the natural environment for any use that can be made of it; (b) injury or damage to property or to plant or animal life; ... (d) an adverse effect on the health of any person; and ... (f) rendering any property or plant or animal life unfit for human use.” (Government of Ontario, 1990b).

The federal *Fisheries Act* provides further impetus for biomonitoring by stating that no person shall carry on any work or undertaking that results in the harmful alteration, disruption, or destruction of fish habitat (e.g., spawning grounds; nursery, rearing, and migration areas; and food supply) (Government of Canada, 1985).

Reflecting on our legislation, Ontario’s policies also suggest a need for biomonitoring. The document, *Water Management: Policies Guidelines Provincial Water Quality Objectives of the Ministry of Environment and Energy* [sic] states:

“With respect to surface water quality, the goal is to ensure that ... water quality is satisfactory for aquatic life...”. (MOEE, 1994).

Similarly, the *Provincial Policy Statement (PPS)*, which is based on the *Planning Act*, states:

“the quality and quantity of ground water and surface water and the function of sensitive ground water recharge/discharge areas, aquifers, and headwaters will be protected or enhanced”. (Government of Ontario, 1997)

The PPS further states that development and site alteration is only permitted in significant habitats if no negative impacts on the natural features or the ecological functions will result.

Biomonitoring is further justified in parks and protected areas by Ontario Parks’ mission statement (e.g., Government of Ontario, 2005): ensuring that “Ontario’s provincial parks protect significant natural, cultural, and recreational environments, while providing ample opportunities for visitors to participate in recreational activities” requires us to have knowledge about the condition of the aquatic biota within our parks and protected areas.

Benthos as Indicators

Benthos are large, bottom dwelling insects, crustaceans, worms, molluscs and related aquatic animals. They are good indicators of aquatic ecosystem health because they are sedentary; their life cycles range in length from months to years; they are easy to collect and identify; they are responsive to changes in water and sediment quality; they are ubiquitous; and they are not typically seen as an economic or recreational resource themselves (Mackie, 2001). Benthos have been used extensively to assess water quality in streams and lakes (Rosenberg and Resh, 1993; 1996b).

Complementarity of Biological and Physical-Chemical Monitoring

Physical-chemical (stressor-based) and biological (effect-based) monitoring approaches are complementary (Table 1). An example of a stressor-based index is the number of skiers visiting Quetico Provincial Park in winter – a surrogate for impact on woodland caribou (*Rangifer tarandus caribou*) foraging success). An example of an effect-based index is the average mass of adult male woodland caribou at age two – a surrogate measure for foraging success and effect of foraging interference by skiers. To illustrate the complementarity of these two types of indicators, consider water quality and benthos data collect-

Table 1. *Complementarity of stressor- and effect-based aquatic monitoring (Source: adapted from Roux et al., 1999).*

	Stressor-based Approach	Effect-based Approach
Monitoring focus	Stressors causing environmental change, i.e., chemical and physical inputs	Effects (responses) of natural and/or anthropogenic disturbances, e.g., changes in the structure and function of biological communities
Management focus	Water quality regulation: controlling stressors through regulations	Aquatic ecosystem protection: managing ecological integrity
Primary indicators	Chemical and physical habitat variables, e.g., pH, dissolved oxygen, copper concentration	Structural and functional biological attributes (e.g., relative taxa abundances, frequency of deformities)
Assessment end points	Degree of compliance with a set criterion or discharge standard	Degree of deviation from a benchmark or desired biological condition

ed in the Pretty River between 1996 and 2001 (Figure 1). The majority of the distribution of data for phosphorus and zinc (stressor-based indicators) were well below provincial water quality objectives (e.g., MOEE, 1994), suggesting good water quality conditions. In comparison to local, minimally impacted Niagara Escarpment stream communities, however, the very low densities of benthos (effect-based indicator) collected in the Pretty River suggested habitat degradation (which was consistent with the site's history as a man-made bed-rock floodway channel). In this case, seemingly contradictory water chemistry and biological monitoring results can be combined to make a more complete assessment of aquatic ecosystem condition than either approach could on its own, i.e., to conclude that water quality is good but that biota are suppressed by habitat degradation.

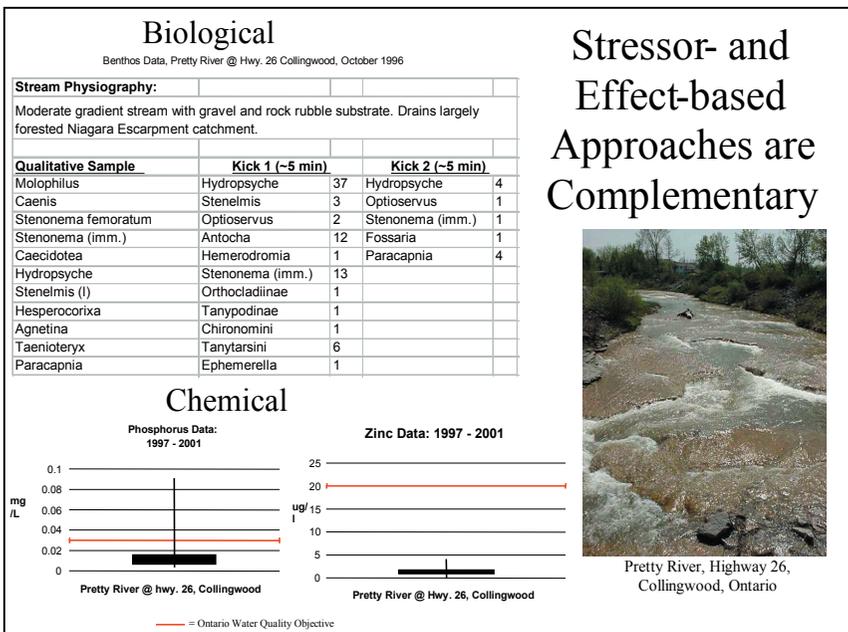


Figure 1. Water chemistry and benthos sampling data for the Pretty River, Collingwood, Ontario. Under the Biological Monitoring heading, table entries are abundances for each listed taxon collected during a five-minute kick and sweep sample. Chemical monitoring charts show box plots for phosphorus and zinc. The central 50% of the data is shown as the box (more variable data has a larger box), with vertical bars extending to the maximum and minimum observed values. Unpublished data (Photo source: Nottawasaga Valley Conservation Authority).

OBBN Vision

Even though the need for benthos biomonitoring is well known, its application has not been widespread in Ontario for a number of reasons: although regulatory guidelines for water chemistry are available, no such ‘biocriteria’ exist for biomonitoring; bioassessment is complex due to a number of confounding factors (i.e., biota respond to factors other than water quality); no standard sampling protocol exists; benthos identification requires special expertise; experts disagree on interpretation; and traditional methods are costly.

A patchwork approach to biomonitoring in Ontario has created a number of barriers to wider application, including no standard protocol, no mechanism for sharing data, and no consistent training. The OBBN will remove these barriers by specifying standard methods, enabling data sharing between partners, automating analysis using a reference-condition approach, and providing training. With the direction of a multi-partner Technical Advisory Committee, we are developing the network according to the principles of partnership, free data sharing, and standardization. EMAN sees the OBBN as a pilot project for a Canada-wide aquatic biomonitoring program.

The Ontario Benthos Biomonitoring Network has five objectives:

- 1) to enable the assessment of lakes, streams, and wetlands using benthic macro-invertebrates as indicators of environmental quality;
- 2) to provide a biological performance measure related to management of aquatic ecosystems;
- 3) to provide a biological complement to the *Provincial Water Quality Monitoring Network*, a water chemistry monitoring program, administered by the Ontario Ministry of Environment, that has been operating since the 1960s;
- 4) to facilitate a reference condition approach to bioassessment in which minimally impacted sites are used to derive a community expectation for a test site; and,
- 5) to support development of aquatic biocriteria and a biological water quality index for Ontario that can be integrated with federal biomonitoring initiatives.

We expect to implement the OBBN fully by 2005. Coordinating partners, MOE and EMAN, are providing scientific guidance and limited sampling

equipment. Partners (federal and provincial ministries, conservation authorities, municipalities, universities, non-governmental groups, and volunteers) are sampling lakes, streams, and wetlands, and they are helping to evaluate OBBN protocols.

Reference Condition Approach

We recommend a reference condition approach (RCA) to bioassessment (Figure 2), in which minimally impacted reference sites are used to define ‘normal’ and set an expectation for community composition at test sites where water and habitat quality are in question (e.g., Wright *et al.*, 2000; Bailey *et al.*, 2004). Using RCA, we consider test sites unusual if their communities fall outside of the normal range. Unusual sites warrant further study to determine if human activities are responsible for the deviant community composition.

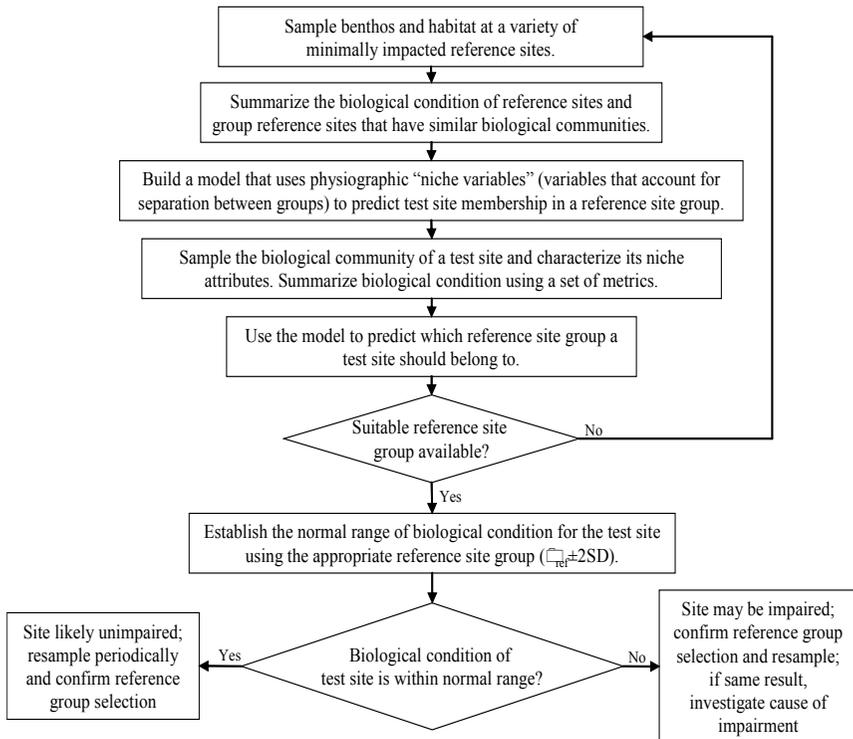


Figure 2. *The reference condition approach.*

The first step in the RCA is to sample reference sites. Because no objective quantitative criteria for ‘minimally impacted’ exist, we ask partners to sample sites that are not obviously exposed to any human impacts (such as point-source contamination, regulation of water level, water impoundment, deforestation, habitat alteration, development, agriculture, or acidification), and that represent best local conditions. Test site sampling will commence once a reasonable amount of reference site data is available.

OBBN Protocol

The OBBN protocol manual (Jones *et al.*, 2004) balances standardization and flexibility. We need standard methods to ensure comparability of data but also need flexibility to accommodate partners with different financial resources and expertise. Table 2 summarizes OBBN protocol recommendations.

Table 2. *Summary of OBBN protocol recommendations.*

Biomonitoring Component	Recommendation
Benthos collection method	Traveling kick and sweep (other optional methods are available for special studies or atypical habitats)
Mesh size	500 μm
Time of year	Any season; assessment comparisons made using data from the same season
Picking	In lab (preferred) or in field (optional); preserved (preferred) or live (optional); microscope (preferred) or visually unaided (optional); random sub-sampling to provide a fixed count per sample
Taxonomic level	Mix of 27 Phyla, Classes, Orders and Families (minimum); more detailed identifications are optional and are recommended for reference sites
Analysis	Reference condition approach

OBBN Database

The OBBN database will be internet accessible. In addition to storing reference and test site data, it will contain several applications that automate the assessment process: a test site and reference site selection utility, a mapping utility, a summary metrics calculator, and a statistical module for hypothesis

testing. These additional modules will allow partners to generate custom assessment reports so practitioners will have instantaneous results in a readable format.

Research Needs

We have identified a number of research questions related to development and evaluation of OBBN protocols. We list these questions below to stimulate discussion and highlight opportunities for collaborative studies:

- Is the reference site mean ± 2 SDs a reasonable definition of the normal range? What is an ecologically significant effect, i.e., the minimum effect size we wish to detect?
- Do taxonomic resolution and sampling method affect sensitivity and diagnostic ability?
- Can we use ‘response signatures’ to identify causes of impairment?
- How many groups of reference sites are there? How many sites are required to define a group?
- How accurately can we predict a test site’s reference group membership? What are the best attributes to build our predictive model on?
- What qualifies as a reference site? How minimally impacted is minimally impacted enough?
- How many samples are enough for whole lake, whole river, or whole wetland assessments?
- Do optional sub-sampling methods yield the same estimates of relative densities?
- What is the ideal ratio of reference sites to number of metrics used in the analysis? Which indices contribute the most information to bioassessments in different parts of Ontario?

Partnership Benefits Specific to Ontario Parks

Ontario Parks' participation in the OBBN will benefit both park managers and other OBBN partners. Ontario's parks and protected areas are very important to OBBN partners because they contain minimally impacted reference sites. Reference sites in parks and protected areas are likely to become increasingly important as land-use changes occur in surrounding areas. Park managers will benefit by having access to a method of evaluating aquatic ecosystem condition that provides both surveillance and performance information related to aquatic ecosystems. The OBBN has established standard procedures, uses a world-renowned indicator, is relatively inexpensive, and provides some flexibility to account for differences in available time and expertise. Furthermore, the network will give instant gratification: bioassessment results, which indicate whether or not a site is within the normal range of biological condition observed at reference sites, will be generated by automated analytical tools, at the click of a button.

Summary

Our key messages presented in this paper are listed below:

- Aquatic biomonitoring is important for adaptive management.
- Benthos are excellent indicators of aquatic ecosystem health.
- The OBBN will remove barriers to benthos monitoring by providing a standard protocol, training, data sharing, and automation.
- We will implement the network by 2005 on the principles of standardization, partnership, and free data sharing.
- The OBBN database will provide custom reports so results are instantaneous and in a readable format. Citizen scientists' assessments will use the same rigorous approach that research scientists use.
- Refining the OBBN protocol requires answering several research questions.

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