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Biomonitoring Our Streams

What's It All About?

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What Is Biomonitoring?

Testing for chemical pollution in our nation's streams has traditionally meant using analytical chemistry. In recent years, environmental agencies have endorsed biological monitoring to enhance or replace chemical monitoring. The theory behind biological monitoring (biomonitoring) is to use the organisms living in the aquatic system as a measure of water quality. This concept was applied to air quality and used by miners who took canaries into deep mines with them. If the canary died, the miners knew the air was bad, and they had to leave the mine.

Biomonitoring an aquatic system uses the same theoretical approach. Aquatic organisms are subject to pollutants in the stream as it flows by, day or night. Consequently, the health of the organisms reflects the quality of the water they live in. If the pollution levels reach a critical concentration, certain organisms will die, migrate away, or fail to reproduce, eventually leading to the disappearance of those species at the polluted site. Normally, these organisms will return if conditions improve in the system.

The three general components of an aquatic ecosystem that influence the biological community are: water chemistry, geomorphology, and hydrology. Each component influences the health of the biological community individually and together. Toxic chemicals are only a single factor within the water-chemistry component. The relation of these three components to each other can be shown on a triangle (figure 1).

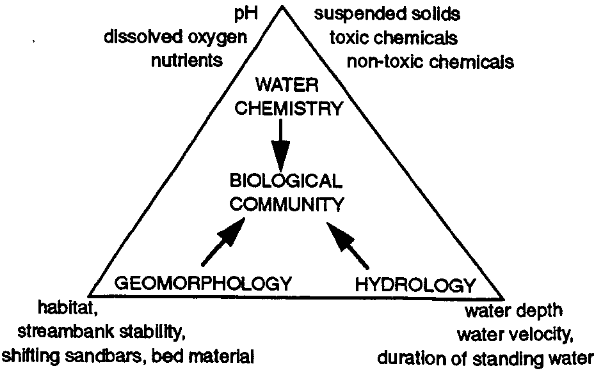


Figure 1. Three general components that influence the biological community composition.

The relative importance of one component may change with time and location. At certain times of the year or in different geographical settings, a single factor may exert primary control on the well-being of the biological community. For example, straightening a stream and removing all woody debris drastically alters a stream's geomorphology. This results in loss of natural habitat and shelter for certain organisms. The organisms that require this shelter will disappear from the modified system. Separating the influence of one component from the others is difficult. **Consideration of all three components and their interactions is critical when interpreting biomonitoring data.**

Factors that control toxicity of a chemical

Two important factors that must always be considered when discussing chemical toxicity are the concentration and the length of exposure. The concept of concentration and exposure are practiced routinely by farmers when they apply pesticides. First, the farmer calculates the concentration required to cover and protect a crop based on the manufacturers' recommendations. Second, the farmer contemplates the length of exposure needed when considering the weather conditions. Prediction of rain will often cause a farmer to postpone spraying because the rain would wash the pesticide off the crop, reducing the length of exposure. A sufficient concentration must be applied over an adequate exposure period for the chemical to be effective. **Concentration and length of exposure are the basic factors that control toxicity of any chemical.**

What is involved in a biomonitoring project?

A biomonitoring project begins with an experimental design and site selection. The next step includes selecting the organisms appropriate for the stream and types of contamination of concern. After the organisms have been selected, the appropriate collection technique must be applied. Finally, once the samples have been collected, identified, and counted, the data must be interpreted. These steps are described in more detail in the following tables.

Table 1. Approaches to site selection and some of the benefits and limitations of each

Approach	Expectation and limitation of results
Paired basin	Two basins with similar features are compared to determine differences in water quality as a result of land use. *Benefits*: Good for comparison purposes. *Limitations*: Difficult to find two basins that are similar in all ways except the one variable being evaluated.
Upstream-downstream	Quality of water entering at a site is evaluated to establish a known baseline condition. Then, the water quality is evaluated again after it has traveled through a defined test site (past a factory, a landfill, a farm, or a wetland). *Benefit*: Changes in water quality that are the result of the test site can be distinguished. *Limitations*: Can only be used on a moderate scale; often the test site (stream or river) has other inputs of water that enter through springs or ditches which contribute to the water quality. All of the inputs must be considered before inferring a cause and effect.
Trend analysis	Trend analysis is used to determine changes in water quality over time as a result of changing management practices. For example, implementing conservation practices or improving a waste-treatment facility should improve water quality over time. *Benefits*: Provides an opportunity to see and quantify improvements in water quality because of changes in operating procedures. *Limitations*: Difficult to see any significant change in water quality over time in large areas because of the variability due to natural events. Thus, many years of data must be gathered before a statistically significant improvement in water quality is demonstrated. This problem can be minimized by running a paired basin study concurrently.

Table 2. Target organisms and some general applications in water-quality monitoring

Category	Application
Bacteria	Detection of certain bacteria indicates sewage contamination.
Algae and aquatic plants	Exceptionally rapid growth of plants and algae typically indicates nutrient enrichment of the surface water. Death during the growing season may indicate acute turbidity (blocking sunlight) or herbicide exposure.
Zooplankton	Microscopic animals that are indicative of toxins, turbidity, and nutrient enrichment. Useful because these organisms have a brief life-cycle, providing a fast response. However, use has been limited by their patchy distribution and the inconvenience of their microscopic size.
Macro-invertebrates	Good general indicators of overall water quality. They are sensitive to water chemistry, hydrology, and geomorphology. Various species have a distinct range of sensitivity to pollutants. Thus, they are often used to indicate various degrees of environmental degradation.
Fish	Good indicators of the ecosystem since fish rely on the other categories for food. Thus, they reflect the overall health of the entire food chain. Their use is limited by their patchy distribution.

Table 3. Sampling techniques and the criteria for use

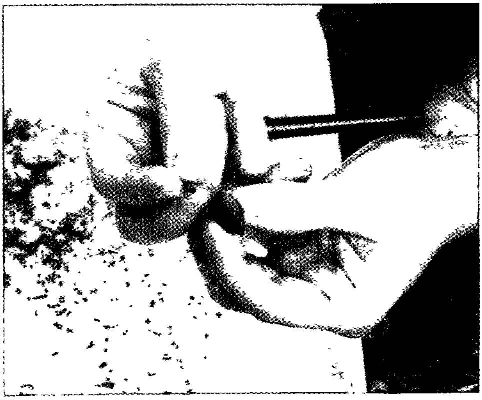
Sampling device	Good for use in the following situations
Grab or scoop samplers	Devices that are designed to penetrate bottom sediment and collect a sample in standing or flowing water. Samples are sifted through a sieve to sort the organisms. Large items like twigs or stones are searched by hand. This technique is primarily used to collect macroinvertebrates and aquatic plants.
Nets:	Used primarily to collect macroinvertebrate, fish, and zooplankton samples.
Kick net	Useful in small streams with gravelly bottoms and good flow velocity. Nets are stretched across the stream and the bed upstream is disturbed by kicking; organisms flow into the net.
Stream net	Long tapering nets with a wide, rigid opening. Nets are secured in place and organisms will passively drift or swim into the net over a 24-hour period. Used for fish and macroinvertebrates, depending on net design and mesh size.
Gill net	Used to sample fish of a certain size range. Useful in large rivers and lakes.
Seine net	Used to sample fish in shallow ponds or streams. A wide net that reaches from top to bottom of the water and is pulled at each end; used to sweep across a shallow body of water and capture fish.
Artificial substrates	Sampling devices made of natural or artificial material. The configuration of the substrates vary with the target organisms. These substrates can consist of ceramic tiles, glass slides, wood plates, leaf packs, cement balls, or other items. Organisms are quantified per a known surface area. This technique is used to collect macroinvertebrates or algae, in rivers, lakes, and streams. Substrates should be placed at the same depth in the water column because different organisms will colonize the substrates at different depths.
Electroshocking	Used in streams, rivers, and lakes. Strong electrical pulses are sent between two electrodes. Fish will move toward the positive pole. This is a nonlethal method to capture fish. **Extremely dangerous technique and should only be done by trained professionals.**

Interpreting the data

Data collected during a biomonitoring study are interpreted in different ways. Usually, the total number of organisms and the number of different species present will be determined. Then these numbers will be applied to an index that lists organisms according to their sensitivity to pollution. This produces an "index of biotic integrity." Other statistical procedures can be used to help interpret the data. In general, a greater diversity of organisms is usually an indicator of a healthy stream. The total number of organisms is not always indicative of the health of the streams. Sometimes a polluted stream can be filled with undesirable species.

A tremendous amount of data and information are required before a direct cause and effect can be assigned with a biomonitoring program. In essence, biological monitoring allows us to look at the effect of changing water quality without necessarily knowing what causes the change. Still, environmental scientists often refer to biomonitoring as more relevant than chemical monitoring in spite of interpretation limits. This is because **biomonitoring measures the environmental consequence of water quality** and not simply the chemical concentration.

In conclusion, biomonitoring provides a quick, pertinent overall environmental picture. This information is important to people who make management decisions aimed at maintaining and protecting the quality of surface waters. Biomonitoring is particularly valuable for alerting people to decaying aquatic conditions just as the canaries alerted the miners to deteriorating air conditions.



Questions to consider when conducting a biomonitoring study:

1. What is the objective of the biomonitoring study?
2. What monitoring strategy should be used to collect the data; an upstream-downstream approach, a paired basin approach, or a trend analysis approach? Refer to table 1 for more information.
3. What target organisms were selected? And, is a seasonal fluctuation associated with the target organisms?
4. Has the appropriate sampling technique been selected for the study?
5. Does the reference site have a similar hydrologic and geomorphic setting compared to the test site?
6. Has the stream bed been modified to change the geomorphology or hydrology? If yes, how will you distinguish between the effects of chemistry and hydrology or geomorphology on the biologic response?
7. Was the biologic index designed for this particular geographic region used? If not, was the standard adapted to the area being studied?

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