ID-228

University of Kentucky
College of Agriculture,
Food and Environment
Cooperative Extension Service

Aquatic Macroinvertebrates: Biological Indicators of Stream Health

*Carmen T. Agouridis, Evan T. Wesley, and Tyler M. Sanderson, Biosystems and Agricultural Engineering, and Blake L. Newton, **Entomology***

What is Stream Health?

Streams are an important part of the landscape. Streams transport water, sediment and energy; provide habitat for aquatic life and support terrestrial life; provide a place for recreation; and in many cases serve as a water supply. The health of streams—or their ability to perform these important functions—is dependent on the conditions of the watersheds which they drain. Changes in land use within a watershed can affect a stream's health (Figure 1).

Figure 1. Lack of shade and high levels of nutrients in runoff results in algal growth and warmer waters which lower dissolved oxygen levels.

A healthy stream is one that is able to support a variety of biological and ecological functions such as filtering and processing of nutrients, organic carbon recycling, sediment transport, and habitat provision (Figure 2). Healthy streams typically have three components: (1) wide riparian buffers consisting of trees and shrubs, (2) a heterogeneous stream bed comprised of riffles with shallow, faster moving water and deep pools with slow moving water, and (3) cool, oxygenated waters with low levels of pollutants such as nutrients and sediments. Fish, aquatic insects (e.g. aquatic macroinvertebrates), algae and other aquatic and terrestrial plants and animals are dependent on the health of a stream. When the health of a stream changes, so too will the life in and around that stream. A healthy stream will support a large and diverse population of species while an unhealthy one will not.

Figure 2. (a) A healthy stream with good physical stability, water quality, and habitat features and (b) an impacted stream with eroding streambanks, an absence of shade, and limited habitat features.

Figure 3. Assessing stream health using (a) physical and (b) chemical methods.

How is Stream Health Assessed?

Because of the relative ease of data collection and analysis, stream health is often assessed through the use of physical (e.g. width, depth, slope, and substrate size) and chemical properties (e.g. pH, temperature, dissolved oxygen, and nutrient concentrations) rather than biological ones (Figure 3). However, biological indicators such as species diversity and numbers help provide a better understanding of a stream's health (Figure 4). Changes in stream health most likely will parallel the biological changes within a stream.

What are Macroinvertebrates?

Aquatic macroinvertebrates are organisms that live in the water (aquatic), are visible with the naked eye without the use of a microscope (macro), and lack an internal skeleton (invertebrate). Examples of aquatic macroinvertebrates include insects, worms, snails, mollusks, and crustaceans. Aquatic macroinvertebrates are typically found living under rocks or logs or living in congregated leaf packs.

Aquatic macroinvertebrates are an integral part of the food chain. Without these creatures, a stream's entire aquatic food web would collapse. Many macroinvertebrates feed on organic material such as leaves and algae. Other higher order organisms such as birds, fish and larger insects then feed on aquatic macroinvertebrates.

Figure 4. Nets are often used when sampling aquatic life to assess the biologic health of a stream.

Why are Aquatic Macroinvertebrates Good Indicators of Stream Health?

Macroinvertebrates are widely recognized as the best biological indicators for stream health.

Because of their short life cycles (generally one year of which most is spent in the water) and relative immobility, aquatic macroinvertebrates are good indicators of stream health. Their survival is directly linked to their habitat. For assessment purposes, the benefit of a short life cycle means that recent changes in water quality are reflected in the macroinvertebrate population. Relative immobility means that relocation is difficult. Aquatic macroinvertebrates cannot quickly move to another stream if the one they are currently living in becomes polluted. This rather stationary life creates an opportunity to use aquatic macroinvertebrates for the assessment of localized stream conditions.

How are Aquatic Macroinvertebrates and Water Quality Linked?

Water quality is one of the main factors controlling the composition of aquatic macroinvertebrate species in a stream. Different aquatic macroinvertebrates have adapted to live in different habitats. Each type of aquatic macroinvertebrate has a different level of pollution tolerance. Some aquatic macroinvertebrates are very sensitive to changes in water quality and can only survive in streams with very little pollution, cool temperatures, and highly oxygenated waters. Other types of aquatic macroinvertebrates can tolerate polluted waters.

One set of aquatic macroinvertebrates commonly used to gage the health of stream are EPT taxa. **E**phemeroptera, **P**lecoptera, and **T**richoptera (EPT)—or more commonly known as mayflies, stoneflies and caddisflies (Figures 5-7). These aquatic macroinvertebrates obtain oxygen through passive gills (gills do not pump but rather absorb oxygen from the surrounding water). Because of their low tolerance to pollution, these aquatic macroinvertebrates are only found in streams with good water quality. Other aquatic macroinvertebrates such as crayfish (Figure 8) and aquatic sowbugs (Figure 9) are moderately sensitive to pollution and are not as helpful as water quality indicators. Other species such as midge larva, pouch snails, and rat-tailed maggots (Figure 10) are tolerant of polluted waters. These tolerant species have developed biological mechanisms such as hemoglobin, lung-like sacs, and tubes, respectively, which allow them to obtain oxygen in difficult environments.

Figure 5. Mayfly nymph, order *Ephemeroptera*. The "E" in EPT. Mayfly nymphs have passive gills and are very sensitive to changes in water quality, especially oxygen depletion.

Figure 6. Stonefly nymph, order *Plecoptera*. The "P" in EPT. Like mayflies, stonefly nymphs have passive gills and are very sensitive to changes in oxygen content.

Figure 7. Pebble "case" of a caddisfly larvae, order *Trichoptera*. The "T" in EPT. Wormlike Trichoptera larvae build small cases from pebbles and sticks. Like mayflies and stoneflies, they are very sensitive to changes in water quality.

When are Macroinvertebrate Assessments Performed?

In accordance with the Federal Clean Water Act, including Sections 401 and 404 which regulate the discharge of pollution into public waterways, macroinvertebrate assessments (sometimes called biological assessments, or biosurveys) are often performed in watersheds that have experienced, or are slated to experience, a change in land use, especially if a waterway (or its riparian zone) is directly altered. For instance, if a private or commercial construction or mining project is planned in a watershed, macroinvertebrate surveys (and other stream assessments) are sometimes conducted before, during, and after the project to determine any impacts to stream health, especially if Federal permits are required, or if Federal funding is being used in the project. In those cases, macroinvertebrate surveys are typically performed by private consultants who specialize in biological surveys. Macroinvertebrate surveys are also conducted (typically by private consultants) before and after state and federal stream restoration projects to determine the success of such projects. In Kentucky, in compliance with the Clean Water Act, surveys are also regularly conducted at strategic sites by the Kentucky Division of Water to monitor impaired waterways and to determine overall stream health in the state.

Figure 8. Rusty crayfish, order *Decopoda*. Crayfish are common in most Kentucky streams. They are tolerant to moderate levels of pollution.

Figure 9. Aquatic sowbug, order *Isopoda*. Like crayfish, sowbugs are found in most Kentucky streams, even those that are moderately impaired.

Figure 10. Rat-tailed maggot, order *Diptera*. Rat-tailed maggots extend the long tube on their abdomen above the water surface to obtain oxygen. This allows them to live in highly polluted and oxygen-poor waters.

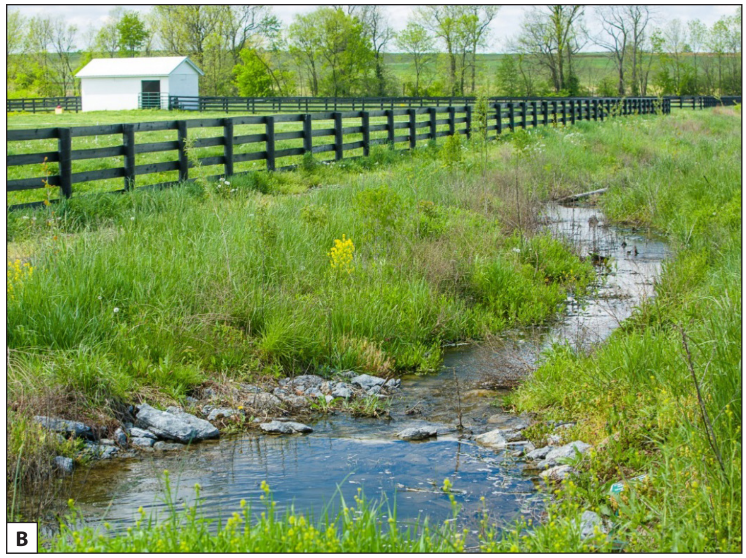

Figure 11. A stream before (a) and after (b) restoration.

What Agencies Offer Macroinvertebrate Training, Education, and Assistance?

Kentucky Water Watch, a program administrated by the Kentucky Division of Water, trains and organizes volunteers to facilitate waterway monitoring projects across the state, including macroinvertebrate surveys. Because volunteers are trained in macroinvertebrate identification, sample-site selection, sampling techniques, and data collection, formal and non-formal educators and students can incorporate Kentucky Water Watch activities into their science curriculum. Kentuckians can visit the Kentucky Water Watch website (http://water.ky.gov/ww/Pages/default.aspx) to learn about joining a volunteer group in their region.

Project managers and property owners who think that they might need macroinvertebrate assessments (or other stream-health assessments) may seek assistance from the Kentucky Division of Water (http://water.ky.gov/Pages/default.aspx) or the Kentucky Division of Compliance Assistance (http://dca.ky.gov/Pages/default.aspx). The Kentucky Division of Water may be able to share baseline stream-health data for certain areas. The Division of Compliance Assistance can help with compliance questions regarding Federal and State permits that relate to macroinvertebrates and waterway health.

Figure 12. Stream restoration projects seeking to improve aquatic macroinvertebrate habitat should focus on riparian buffers and riffles.

How is Stream Health Improved?

Aquatic macroinvertebrate populations are influenced by physical parameters such as riparian buffer width and channel geomorphology as well as chemical parameters (i.e. water quality). Increasing the number and diversity of aquatic macroinvertebrates in streams means improving both the physical and chemical components of streams. The level of intervention needed varies with each impacted stream. In some instances, planting a riparian buffer is sufficient. In other instances, a greater level of intervention such as altering the stream's physical structure (i.e. stream restoration) or reducing nonpoint source pollution in the watershed is required (Figure 11).

Stream Restoration and Aquatic Macroinvertebrates

Riparian buffer establishment and riffle construction are the two aspects of stream restoration that most directly impact aquatic macroinvertebrates (Figure 12). With riparian buffer establishment, trees and native grasses provide a number of benefits such as shade, strength to streambanks, carbon inputs, and pollutant filtration. Shade helps lower water temperatures, which in turn increases dissolved oxygen levels in the water. The roots of trees and native grasses helps hold the streambank soils together thus reducing and/or preventing erosion. Trees input carbon into streams through leaves, twigs and large woody debris. It is this carbon which serves as a food source for many aquatic macroinvertebrates. Lastly, trees and especially native grasses help filter nutrients and sediment from runoff thus preventing these pollutants from entering streams.

Riffle construction, specifically long riffles, are beneficial to aquatic macroinvertebrates. It is in these riffles where dissolved oxygen levels are higher, where cobbles and large gravels provide shelter for aquatic macroinvertebrates, and where leaf packs and other organic debris get snagged on larger rocks and large woody debris.

Resources

Kentucky Critter Files (http://www.uky.edu/Ag/CritterFiles/casefile/casefile.htm)

Living Along a Kentucky Stream (IP-73)

Planting Along Your Stream, Pond, or Lake (HENV-202)

Reducing Stormwater Pollution (AEN-106)

Restoring Streams (AEN-122)

Riparian Buffer Planting (ID-185)

United States Environmental Protection Agency, Water homepage (http://water.epa.gov/)

Kentucky Water Watch (http://water.ky.gov/ww/Pages/default.aspx)

References

Carlisle, D.M., M.R. Meador, T.M. Short, C.M. Tate, M.E. Gurtz, W.L. Bryant, J.A. Falcone, and M.D. Woodside. 2013. The quality of our Nation's waters—Ecological health in the Nation's waters, 1993-2005. U.S. Geological Circular 1391.

Kentucky Division of Water. 2013. Kentucky watershed watch high gradient biological stream assessment standard operating procedure WWSOP03000. Kentucky Water Watch Program.

Voshell, Jr., J.R. 2002. Guide to Common Freshwater Invertebrates of North America. McDonald and Woodward Publishing Company, Granville, OH.

Acknowledgement

Funding for this publication was provided in part by an Urban Waters grant from the U.S. Environmental Protection Agency.

Figure Credits

Carmen Agouridis, Biosystems and Agricultural Engineering
Figures 1, 2, 3a, 11a, and 12

Matt Barton, Agricultural Communication Services
Figures 3b, 4, and 11b

Blake Newton, Entomology
Figures 5, 6, 7, and 9

U.S. Geological Survey Archive, U.S. Geological Survey, Bugwood.org
Figure 8

Whitney Cranshaw, Colorado State University, Bugwood.org
Figure 10

Issued 5-2015