

The Alabama Watershed Demonstration Project: Biotic Indicators of Water Quality

There has been serious concern about declining water quality in streams and rivers since the 1960s. Initially, concerns were centered on releases of point source pollutants such as heavy metals, sewage, and other chemical wastes from industrial and municipal origins. These were harmful both to human and stream ecosystem health. For this reason, the Clean Water Act (CWA) was enacted in 1977 to “restore and maintain the chemical, physical, and biological integrity of the Nation’s waters.” In 1987, Section 319 of an amendment to the CWA created policy to control nonpoint source water pollution—pollution that can occur from sediment and pesticide runoff from farms, residential areas, construction sites, and mines.

High nonpoint source runoff may change stream water color and turbidity (clarity), increase the amount of organic matter and nutrients (usually nitrogen and phosphorus), and increase sediment suspended in the water. Once in streams, these materials separately or in combination can seriously degrade water quality for humans and aquatic life. Unlike point source pollution, nonpoint source pollution is much more difficult to detect and control because runoff does not come from a few easily identifiable sources, but instead stems from a number of locations scattered across a watershed. Nonpoint source pollution is among the most

important sources of water quality impairment. It is the primary source of pollution from logging operations in forested watersheds in the United States.

The traditional water quality monitoring approach has been to collect stream water samples and analyze them in a laboratory for suspected physical and chemical pollutants. Unfortunately, because sampling and analysis are expensive and because concentrations of pollutants vary greatly with time and location, physical and chemical monitoring alone often cannot detect nonpoint source pollution problems.

A biological approach to water quality monitoring—biomonitoring—incorporates the use of stream organisms themselves as a basis for pollution detection. Europeans first adopted this strategy in the early 1900s to identify organic pollution in large rivers. In the United States, the use of stream organisms as biological indicators or “sentinels” has become widespread only over the last two decades. Several agencies including the Environmental Protection Agency (EPA), the Natural Resources Conservation Service (NRCS), and the U.S. Geological Survey (USGS) now employ biologists whose main task is to implement biomonitoring in streams and rivers across the country. The underlying concept of biomonitoring is simple: certain types of stream animals occur or thrive only under

certain water quality conditions. When conditions change, such as when a stream receives significant nonpoint source runoff, the abundance and distribution of animals in the affected site change as well.

Although fish and algae have been used in stream biomonitoring programs, benthic invertebrates are the most commonly used organisms. Benthic invertebrates are widely used as bioindicators because

- They constitute the majority of species present in streams.
- The numerous species present often show a wide range of sensitivity to pollution.
- They are relatively easy to sample and identify.
- The short life cycles and high movement of many species may provide reliable and rapid evidence of the return of favorable water quality after a pollution event.

The combined use of benthic invertebrate bioindicators and traditional stream water quality monitoring allows a comprehensive means of assessing water quality pollution from nonpoint sources within forested watersheds.

What Are Benthic Invertebrates?

Benthic invertebrates are small animals that live on the bottom of a pond, lake, stream, or river for at least part of their lives. They inhabit tiny spaces between submerged stones, within organic debris, on logs and aquatic plants, or within fine sediments (silt, clay). Technically, invertebrates are animals that do not have backbones like the larger animals (vertebrates) such as fishes, amphibians, reptiles, birds, and mammals.

Benthic “macroinvertebrates” are bottom-dwelling invertebrates large enough to be seen with the naked eye. They are usually greater than 1 mm or $\frac{1}{32}$ inch long. Most species of stream macroinvertebrates are aquatic insects (see below), although crustaceans (crayfish, sideswimmers, aquatic pillbugs), molluscs (snails, mussels, clams), oligochaetes (earthworms, leeches), and arachnids (aquatic mites) also occur commonly.

General Guide to Aquatic Insects Found in Streams

Following is a description of features that may help you identify seven of the groups (orders) of aquatic insects found commonly in streams. Consult the references at the end of this publication for more detailed information on identification and on the biology and ecology of these or other invertebrates.

Mayflies (Order: Ephemeroptera). These are aquatic insects whose immature stages (nymphs) usually have two or three tails (caudal filaments), flattened or fingerlike gills on the abdomen, and one claw at the end of each leg. Nymphs may be strongly flattened (Figure 1) or more cylindrical (Figure 2). Adults are terrestrial, meaning they live on land.



Figure 1. Flattened mayfly nymph (Family: Heptageniidae). Photo courtesy of Howell Daly.



Figure 2. Cylindrical mayfly nymph (Family: Leptophlebiidae). Photo courtesy of Ralph Charlton.

Stoneflies (Order: Plecoptera). Stonefly nymphs often are confused with mayflies; they differ in that they always have two caudal filaments (never three), usually lack abdominal gills (some have fingerlike gills on the thorax, or midsection, at the base of each leg), and have two claws at the end of each leg (Figure 3). Like mayflies, most stonefly nymphs are flattened. Adults are terrestrial.

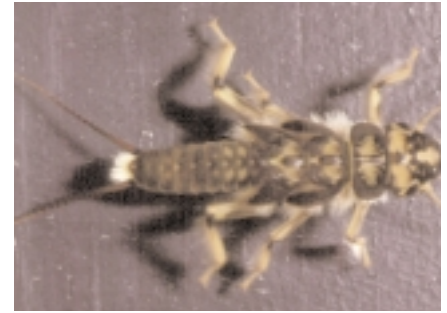


Figure 3. Perlid stonefly nymph (Family: Perlidae).

Damselflies and Dragonflies (Order: Odonata). Immature damselflies and dragonflies (naiads) have a modified lower lip (labium) that is often strongly toothed and scoop-shaped and is used as a spear for catching prey. Damselflies typically are slender, with large, thin gills at the end of the abdomen (Figure 4). Dragonflies have more husky bodies and no external gills on the abdomen (Figure 5). Adults of both groups are terrestrial.



Figure 4. Damselfly naiad (Family: Coenagrionidae). Note the three leaf-like gills at the end of the abdomen.

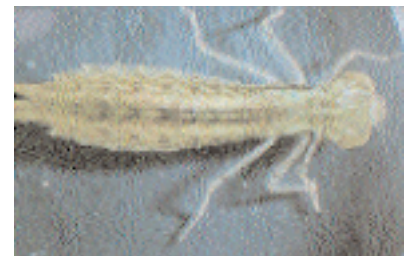


Figure 5. Dragonfly naiad (Family: Aeshnidae).

Caddisflies (Order: Trichoptera). Caddisfly immatures (larvae) are caterpillar-like with fleshy (whitish) abdomens, a dark brown head and thorax, and three pairs of well-developed legs close to the head. The last abdominal segment bears a pair of fleshy appendages with hooks. Larvae may build and live within cases made from wood, leaf fragments, or inorganic materials such as fine sand (Figure 6), or they may be free living (Figure 7). Adults are terrestrial and resemble small moths.

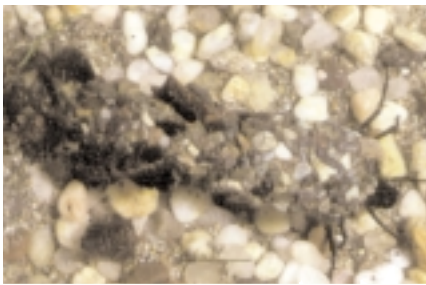


Figure 6. Overhead view of case-building caddisfly larva inside its stony case (Family: Limnephilidae). Note the head and legs emerging from the case on the right side of photograph.



Figure 7. Free-living caddisfly larva (Family: Hydropsychidae). Photo courtesy of Ken Fritz.

True Flies (Order: Diptera). In terms of species, this is the largest and most widespread group of stream insects. Larvae lack legs (although they may have a single, stubby projection, called a “proleg,” near the head) and have soft, fleshy bodies; a head may or may not be present. Three groups containing larvae common to streams are black flies (Figure 8), crane flies (Figure 9), and midges (Figure 10). Adults are terrestrial and often resemble mosquitoes.



Figure 8. Black fly larva (Family: Simuliidae). Note the brown head and single fleshy proleg.



Figure 9. Crane fly larva (Family: Tipulidae). The swollen area on the left is a modification of the abdomen that aids in movement. Photo courtesy of Lara Panayotoff.

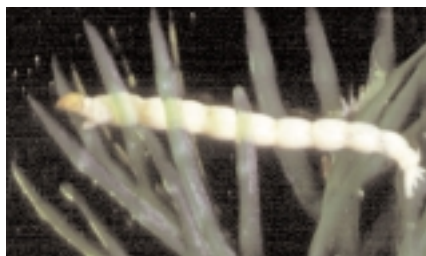


Figure 10. Midge larva (Family: Chironomidae). Note the small yellowish head and single proleg on the left.

Beetles (Order: Coleoptera). Larvae are extremely variable in form, with bodies ranging from a slender, crescent shape (such as riffle beetles, Figure 11) to a highly flattened form (such as water pennies, Figure 12). With most aquatic insects only the immature stages are aquatic and the adults are terrestrial or capable of flight. Adult beetles, however, are often as common in streams as are the larvae. Adults usually display the typical beetle-like appearance—small, dull-colored with extremely hard bodies.



Figure 11. Riffle beetle larva, left, and adult, right, (Family: Elmidae). Photo courtesy of Lara Panayotoff.

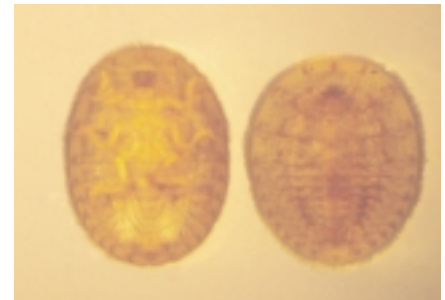


Figure 12. Water penny beetle larva underside, left, and upperside, right, (Family: Psephenidae). Photo courtesy of Lara Panayotoff.

Dobsonflies (Order: Megaloptera). Larvae of this group (hellgrammites) are similar to caddisflies except that they have long lateral projections (filaments) and/or gills on the abdomen, strong heads with large jaws (mandibles), and are usually larger (Figure 13). Adults are terrestrial.



Figure 13. Dobsonfly larva (hellgrammite; Family: Corydalidae). Note the large head and jaws and lateral filaments on abdomen. Photo courtesy of George Folkerts.

How Are Benthic Invertebrates Used in Biomonitoring?

Typically, benthic invertebrates are sampled from streams using dip nets or kick screens for qualitative collections (Figure 14) or quadrat samplers such as a Surber or Hess sampler for more precise, quantitative collections (Figure 15). After collection, the samples are examined either in the field or in the laboratory. The invertebrates are removed from stones and organic debris, identified as belonging to a particular taxonomic group, and counted. Once counted, invertebrates can be compared to samples taken in the same stream but at different times, such as before and after a suspected pollutant has entered a stream. They also can be compared to samples taken from two or more streams at approximately the same time, such as from a stream suspected of receiving a pollutant and a nearby undisturbed reference stream.



Figure 14. Use of aquatic dip net to collect benthic invertebrates in Coastal Plains streams. Flow is from right to left of photograph.



Figure 15. Use of a Surber quadrat sampler to quantify benthic invertebrates from a known area of stream bottom (1 ft²). Flow is from left to right of photograph.

Invertebrates may be quantified by species richness (number of unique types of invertebrates present in a sample), abundance (total number of invertebrates in a sample), relative abundance (number of invertebrates in the sample from one species relative to another), and species diversity (distribution of total individuals across species in the sample).

One very popular biomonitoring metric is the “EPT” index. This is a measure of the total number of species within the three most pollution-sensitive aquatic insect orders:

- Ephemeroptera** (mayflies),
- Plecoptera** (stoneflies), and
- Trichoptera** (caddisflies).

This index assumes that streams showing high EPT richness are less likely to be polluted than are streams showing relatively low EPT richness in the same region.

Importance of Reference Streams

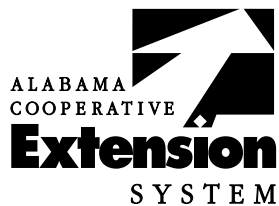
Because streams differ by many natural factors besides nonpoint source pollution, it is critical to establish a baseline or reference condition upon which differences or changes in water quality resulting from pollution can be judged. Water chemistry (e.g., whether streams drain chalky limestone or more dense sandstone rocks), the nature of the stream bottom and its slope, flow regimes, amount of light, temperature, and other watershed features can greatly affect invertebrate communities independent of human influences. For example, benthic research on undisturbed forested watersheds from four different ecoregions of the southeastern United States (Blue Ridge, Southwestern Appalachians, Piedmont, and Coastal Plains) revealed that streams from different ecoregions can show large, natural differences in invertebrate communities. Total invertebrate and EPT richness often may be higher in upland streams of the Blue Ridge or Southwest Appalachians than in lowland Piedmont or Coastal Plains streams. This demonstrates that stream invertebrates can vary geographically according to differences in natural watershed attributes, and measures such as the EPT index are useful in recording such natural variation. Thus, some measure of reference conditions that incorporates natural variation must be established if biomonitoring is useful in pinpointing changes resulting from nonpoint source impacts in streams.

Application of Biomonitoring in Alabama Streams

The biomonitoring approach described in this publication is currently being used with conventional water quality sampling in the Alabama Watershed Demonstration Project (AWDP). This project is centered within the Sepulga River Basin (Butler, Crenshaw, and Conecuh counties) in south-central Alabama. The main objective of the AWDP is to examine if nonpoint source physical, chemical, and biological measures of water quality are related to a mixture of human activities within the Sepulga Basin. The biomonitoring aspect of AWDP is specifically designed to evaluate whether stream benthic invertebrate communities differ in watersheds showing dissimilar amounts of silvicultural, agricultural, or residential land use and, in turn, assess if invertebrate-based measures of water quality are useful in describing differences in land use within watersheds of the Gulf Coastal Plain.

References

- Kellogg, L. L. 1992. Save our streams monitor's guide to aquatic macronivertebrates. Izaak Walton League of America, Arlington, Virginia.
- Klemm, D.J., P.A. Lewis, F. Fulk, and J.M. Lazorchak. 1990. Macroinvertebrate field and laboratory methods for evaluating the biological integrity of surface waters. EPA/600/4-90/030. U.S. Environmental Protection Agency, Office of Modeling, Monitoring Systems, and Quality Assurance. Washington, D.C.
- McCafferty, W.P. 1983. Aquatic entomology. Jones and Bartlett Publishers, Boston, Massachusetts.
- Merritt, R.W. and K.W. Cummins, editors. 1996. An introduction to the aquatic insects of North America. 3rd edition. Kendall-Hunt Publishers, Dubuque, Iowa.
- Resh, V.H., J.W. Feminella, and E.P. McElravy. 1990. Sampling aquatic insects. Department of Entomological Sciences and Office of Media Services, University of California, Berkeley, California.
- Rosenberg, D.M. and V.H. Resh, editors. 1993. Freshwater biomonitoring and benthic macroinvertebrates. Chapman and Hall, New York, New York.
- Thorp, J.H., and A.P. Covich, editors. 1991. Ecology and classification of North American freshwater invertebrates. Academic Press, San Diego, California.
- U.S. Department of Agriculture, Soil Conservation Service (Now NRCS). 1988. Water quality indicators guide: surface waters. NRCS-TP-161. Washington, D.C.



ANR-1167

Jack W. Feminella, Associate Professor, Biological Sciences, and **Kathryn M. Flynn**, *Extension Forester and Coordinator*, Associate Professor, Forestry, both with Auburn University

For more information, call your county Extension office. Look in your telephone directory under your county's name to find the number.

Issued in furtherance of Cooperative Extension work in agriculture and home economics, Acts of May 8 and June 30, 1914, and other related acts, in cooperation with the U.S. Department of Agriculture. The Alabama Cooperative Extension System (Alabama A&M University and Auburn University) offers educational programs, materials, and equal opportunity employment to all people without regard to race, color, national origin, religion, sex, age, veteran status, or disability. UPS, 6.5M30, **New Dec 1999**, ANR-1167