STREAM BIOSURVEYS

Introduction

Organic pollution in streams can result in the loss of many desirable aquatic species including fish and mussels

As human populations have grown, more and more pollution of our waters has occurred, both from point source discharges and as nonpoint or diffuse pollution. There are several categories of pollution associated with the aquatic environment (e.g. toxic pollution), but one of the most common categories is *organic pollution*. This is caused by oxygen-demanding wastes such as domestic sewage, leachate from landfills, and agricultural and urban runoff.

The natural processes of chemical oxidation and biological decomposition that occur within water-courses, consume dissolved oxygen. Decomposition of materials is a normal process in all aquatic ecosystems and is a function of decomposers such as bacteria and fungi. These organisms play an important role by metabolizing organic matter as an energy and nutrient source and use dissolved oxygen in the process.

However, serious consequences to aquatic organisms can result if the natural mechanisms that clean the water are overloaded by large influxes of organic pollution. Severe oxygen depletion can result in the loss of many desirable aquatic species including fish (e.g. trout) and mussels, and aquatic organisms such as stoneflies and mayflies.

Water Quality Testing

Traditional Methods

The long-term effects of nonpoint source pollution, such as that from urban runoff, have often been determined through chemical monitoring. In recent years, however, a growing body of literature has emerged that points to the importance of biological monitoring. Many states are now selecting biological and physical monitoring over traditional chemical monitoring in their efforts to determine the health of aquatic ecosystems, and for watershed and landuse planning purposes.

A single sampling of stream chemical constituents only provides a snapshot of water quality

Traditional water quality sampling methods have emphasized analyses of physical and chemical parameters such as dissolved oxygen, pH, temperature, nitrates, phosphates, and others. Although useful, this approach has several limitations. There are many chemical constituents that could theoretically result in water quality degradation. Not only are some of these very expensive to analyze, but their sheer number increases the likelihood that a pollutant will not be identified. A single sample can only provide a "snapshot" of water quality on the day of sampling, and may provide no information on recent degraded conditions which have since cleared up, but whose effect upon aquatic biota may be more lasting.

Benthic Organism Sampling

Biosurvey Methods

The technique of stream benthic organism or macroinvertebrate sampling was developed more than 50 years ago to complement traditional chemical water quality approaches, as well as to provide new information not available through other methodologies. This includes information about effects from multiple stressors (e.g. chemicals, sedimentation, exotic species, etc.) arising from point sources, nonpoint sources, habitat alteration, and hydrological changes. For example, ecological responses to such disturbances can be observed at the community level of organization of benthic macroinvertebrates, offering dependable and readily observable indicators that integrate the impacts of multiple, and often subtle, stressors.

What Are Benthic Macroinvertebrates?

Benthic organisms can serve as biological indictors of water pollution

The term "benthic" means bottom-dwelling. Benthic macroinvertebrates are organisms without backbones that live in, crawl upon, or attach themselves to bottom substrates (e.g. sediments, debris, logs, plants, filamentous algae, etc.). The term "macroinvertebrate" refers to those organisms that are large enough to be viewed without the aid of a microscope and that are retained by a sieve with mesh sizes greater or equal to 200 to 600 micrometers (i.e. #30 mesh). Benthic macroinvertebrates include immature insects (larvae and nymphs), worms, crustaceans, mollusks, (clams and mussels), leeches, mites and snails. Insect larvae tend to be the most abundant macroinvertebrates in freshwater aquatic systems.

The majority of benthic macroinvertebrates are found in the riffles (i.e. erosional areas) of streams. Riffles range from uneven bedrock to cobbles to boulders. The optimum riffle area contains gravel-sized (1-inch diameter) to cobble-sized (10-inch diameter) substrate. The flow of water over these areas provides plentiful oxygen and food particles. Riffle-type organisms may also be associated with submersed or overhanging fallen woody debris. Riffle-dwellings communities are made up of macroinvertebrates that generally require high dissolved oxygen levels and clean water. Most of these organisms are intolerant to pollution. In slow flow areas such as runs and pools (depositional areas), decomposer communities, which tolerate lower dissolved oxygen levels and higher organic matter and sedimentation, are typically more abundant. Riffle-dwelling communities are more sensitive to increasing pollution than communities in the pools or slow flowing areas of the same stream.

There are four primary feeding groups of benthic macroinvertebrates: shredders, filter collectors, grazers, and predators. Shredders such as stoneflies (*Plecoptera*) feed on plant material and some animal material, which is generally dead, and break it down into smaller particles through their feeding and digestive process. Collectors, such as caddisflies (*Trichoptera*) and blackflies (*Diptera*), feed on fine particulate matter that they filter from the water. Grazers, such as snails and beetles (*Coleoptera*), feed on algae and other plant material living on rocks and on plant surfaces. Predators such as dobsonflies (*Megaloptera*) or dragonflies (*Odonata*) feed on other macroinvertebrates. Individual species may be generalists, and fit into more than one of these groups (as opposed to specialists).

Benthic macroinvertebrates, as a group, exhibit a relatively wide range of response to chemical and physical water quality stressors (pH, temperature, dissolved oxygen, organic pollutants, heavy metals, sedimentation, etc.) and thus can serve as ***biological indicators*** of water pollution. Some organisms are tolerant of degraded water quality conditions, while others are pollution-sensitive. Many snails, worms and midge larvae belong to the former group, while the most widely recognized members of the latter group are the *Plecoptera* (Stoneflies), *Ephemenoptera* (Mayflies) and *Trichoptera* (Caddisflies).

In most cases, unpolluted streams will support a diverse population of macroinvertebrates

Some pristine streams have a low diversity of macroinvertebrate fauna because of the cold temperature and/or relatively low nutrient levels. Headwater streams may have only two or three dominant species. In most cases, however, an unpolluted stream will support a diverse population of macroinvertebrates, with pollution-sensitive species well represented. However, species diversity declines as water quality deteriorates and pollution-tolerant organisms become increasingly dominant.

Advantages of Macroinverterbrate Sampling

Plafkin et al. (1989) list several advantages of sampling stream macroinvertebrates in order to make inferences about water quality:

1. Since most stream macroinvertebrates have limited migration patterns or are sessile and spend much time clinging to rocks or the stream substrate, and do not move long distances, they are good indicators of localized water conditions.

2. Aquatic organisms integrate the effects of chemical, physical and biological parameters. Conducting an aquatic biosurvey will thus increase the likelihood that a degraded condition will be detected, if present.

3. Since most of these species have a relatively short life cycle (approximately one year), they will respond to stressors more rapidly than other longer-lived components of the community (e.g. fish).

4. Sampling techniques are rapid and inexpensive. An experienced biologist can detect degraded water conditions with only a cursory, or qualitative, examination of the macroinvertebrate community.

5. Benthic macroinvertebrates are a primary food source for fish, and as such can provide valuable information on the relative health of the fish community.

6. Benthic macroinvertebrates are common to abundant in most streams.

Sampling Methods

The simplest method of collecting stream macroinvertebrates is to inspect in-stream rocks for attached organisms, or disturb the stream substrate while placing a net downstream to gather dislodged biota in a predetermined number of sampling locations, often 11 approximately one foot square areas of substrate in the state of Connecticut. Depending upon the nature of the study, the organisms are identified to either the family, genus or species level. Family-level identification is most expeditious, and is the technique most commonly used. However, it is less precise since members of some stream macroinvertebrate families show a range of pollution tolerances, and the sensitivity of these families can only be expressed as an average (Hilsenhoff 1988).

Measuring Biological Health

The Biotic Index

A variety of useful indices or measurements (metrics) have been developed for assessing the health of streams through benthic macroinvertebrate sampling. These include: taxa richness, EPT Index or richness, percent abundance of EPT, percent dominance, percent dominance of scrapers, Hilsenhoff s Biotic Index (HBI), EPT:chironomid ratio, Pinkham and Pearson community similarity index, and many others.

Of these, and there are many, Hilsenhoff s (1988) biotic index (HBI) is one of most commonly used. Hilsenhoff developed a rapid stream biosurvey methodology that requires identification of macroinvertebrates to family-level. This method assigns a numerical score (biotic index) ranging from 0 to 10 to the most common stream macroinvertebrate taxa. The biotic index is directly related to the degree of pollution-tolerance and is based on field and laboratory responses of organisms toward organic pollution.
Approximately 100 organisms are collected and randomly sampled from a variety of habitats within the stream, including erosional and depositional areas (e.g. riffles and runs). The organisms are identified to family-level and the total number (**n**i) of each is recorded. The following formula is then used for the estimation of the Family-level Biotic Index (FBI):

$$FBI = \frac{\Sigma \, n_i a_i}{N}$$

where:

n_i = the number of specimens in each taxonomic group

a_i = the pollution tolerance score for the taxonomic group (see Table 1)

N = the total number of organisms in the sample (usually 100).

Ideally, the Family-level Biotic Index should be calculated during several different times of a year (e.g spring, summer and fall) and compared with reference sites within the particular watershed or in the region for more accurate conclusions to be drawn.

Who Can Take This Pollution?

Introduction

It is well documented that pollution of streams reduces the number of species of the aquatic ecosystem, (i.e. species diversity), while frequently creating an environment that is favorable to only a few species (i.e. pollution-tolerant forms). Thus, in a polluted stream, there are usually large numbers of a few species, while in a clean stream there are moderate numbers of many species.

For instance, turbidity reduces light penetration and submerged aquatic plant productivity. Thus turbidity will affect those macroinvertebrates depending on plant matter for food and those that rely heavily on visual location of prey (predators). Filter feeders' filtering mechanisms may also be blocked by sediment particles associated with turbid waters. Turbidity also tends to increase temperature in waters and is often associated with higher organic decomposition. These are conditions that reduce oxygen levels and may result in impacts to many gill-breathing mayfly, stonefly, and caddisfly larvae that thrive only where there is abundant oxygen in the water. As turbidity increases - and turbidity is often associated with other pollutants such as nutrients, PAH s, and heavy metals - rock dwelling or attaching macroinvertebrates such as mayflies, stoneflies, and caddisflies, will be replaced by silt-tolerant and pollution tolerant macroinvertebrates that can tolerate low oxygen levels in the water or that can breath atmospheric oxygen. For example, rat-tailed maggots have snorkel-like breathing tubes, some snails have lungs (e.g. *Physa* spp.), and midges (chironomids) and worms (oligochaetes) have respiratory pigments which enable them to more efficiently obtain oxygen that is in low concentrations.

Pollution *Intolerant* Macroinvertebrates

The following are some typical macroinvertebrate groups (taxa) commonly encountered in streams and that usually indicate ***good water quality***.

Mayflies

Mayfly nymphs are often the most numerous organisms found in clean streams. They are sensitive to most types of pollution, including low dissolved oxygen (less than 5 ppm), chlorine, ammonia, metals, pesticides and acidity. Most mayflies are found clinging to the undersides of rocks.

Stoneflies

Stonefly nymphs are most limited to cool, well-oxygenated streams. They are sensitive to most of the same pollutants as mayflies except acidity. They are usually much less numerous than mayflies. The presence of even a few stoneflies in a steam usually suggests that good water quality has been maintained for several months prior.

Caddisflies

Caddisfly larvae often build a portable case of sand, stones, sticks, or other debris. Many caddisfly larvae are sensitive to pollution, although a few are moderately tolerant. One family spins nets to catch drifting plankton, and is often numerous in recovery zones below sewage discharges.

Beetles

The most common beetles in streams are riffle beetles and water pennies. Most of these require swift current and an adequate supply of oxygen, and are generally considered to be clean water indicators.

Pollution *Tolerant* Macroinvertebrates

The following are some typical macroinvertebrate groups that are commonly encountered in streams and which usually indicate ***poor water quality***.

Midges

Midges are the most common aquatic flies. The larvae occur in almost any aquatic situation. Many species are very tolerant to pollution; most of these are red and are called bloodworms . Other species filter suspended food particles, and are numerous in sewage outfall recovery zones.

Worms

The segmented worms include the leeches and the small aquatic earthworms. The latter are more common, though usually unnoticed. They burrow in the substrate and feed on bacteria in the sediment. They can thrive under conditions of severe pollution and very low oxygen levels.

Sowbugs

Aquatic sowbugs are crustaceans that are often numerous in situations of high organic content and low oxygen levels. When abundant they can indicate a stream segment in the recovery stage of organic pollution.

Black Flies

Black fly larvae have specialized antennae for filtering plankton and bacteria from the water, and require a strong current. Most species are numerous in the decomposition and recovery zones of sewage outfalls and are generally indicative of at least moderate levels of organic pollution.

How have Landuses Affected the Quinnipiac River & its Tributaries?

The water quality of any waterway reflects both the landuses and the geology of its watershed (drainage area), in terms of the mix of chemical constituents, including metals, nutrients, and other pollutants of human origin.

Farms, Yards and Construction Sites

In colonial days up until the beginning of the 1900's much more of the land close to streams and rivers was cleared for farming. This meant soil and manure washed excessive nutrients into streams. Excess fertilizer and pet droppings, streamside clearing, and runoff from construction sites have similar effects. Less shade on watercourses usually means warmer water temperatures and lower dissolved oxygen levels, and fewer "sensitive" aquatic invertebrates. Riverbound Farm in Northeast Cheshire and the north part of Quinnipiac River State Park, in North Haven both had farms along the Quinnipiac River in the beginning of the century. Farming still affects water quality, especially by two major tributary streams on the east side of the watershed, Wharton Brook in Wallingford and the mid and lower Muddy River in North Haven.

Filling Wetlands

Filling wetlands in the upper watershed causes downstream flooding, and also summer low flow problems, as water storage capacity is diminished. This has happened along Harbor Brook in Meriden, and also along parts of Misery Brook in the southeast corner of Southington.

Industrial Discharges & Runoff from Impervious Surfaces

The extent of water quality impacts of point discharges from industrial landuses depends on the effectiveness of pollution regulations. Before the 1972 Clean Water Act was passed, industrial pollution was very severe along the mainstem of the Quinnipiac; only very pollution tolerant aquatic organisms could have survived. Pollutants left over from this era may still contaminate river sediment and riverside soils. Polluted ground water sometimes still seeps into waterways, especially in older manufacturing areas.

Industrial and commercial landuses and highways occupy much land area along the mainstem river, especially in Plainville, Southington, Wallingford, and in the lower watershed. Much of these areas are occupied by pavement and rooftops, which are non-absorbant. Pollutants like heavy metals, leaking vehicle fluids and fine dust from engine, tire, and road wear wash into catch basins and then into the river. Air pollution fall-out also washes off roads and roofs. Litter washes into catchbasins, though culverts, and then into streams. This nonpoint source pollution can be reduced by specially designed grassed swales, filter cartridges, and biofilter detention ponds, etc. Today, somewhat pollution—tolerantmacro-invertebrates, like midge larvae are common along the main stem Quinnipiac River, but not more pollution-sensitive creatures, like stoneflies and mayflies.

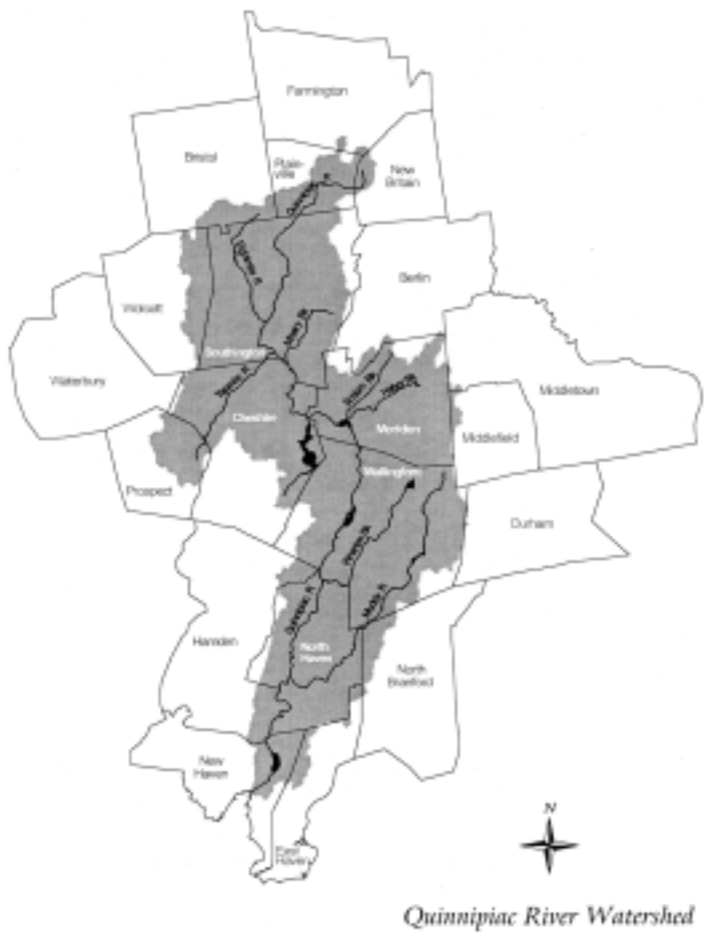
Forested Watersheds

Pollution intolerant creatures (stoneflies and mayflies) live in mostly forested cleaner upper tributaries of the Quinnipiac River, which drain off our trap rock ridges and off Mt. Southington, a granite-schist-gneiss ridge.

References:

Hilsenhoff, W. L. 1988. Rapid field assessment of organic pollution with a family-level biotic index. J. N. Am. Benthol. Soc. 7(1):65-68.

Plafkin, J. L, M. Barbour, K. D. Porter, S. K. Gross, and R. M. Hughes. 1989. Rapid Bioassessment Protocols for use in streams and rivers. US EPA. EPA/440/4-89/001



Map produced by the CT DEP

Developed and produced by ***Rema Ecological Services, LLC*** of Manchester, Connecticut, on behalf of the Quinnipiac River Watershed Association, for the River Resources Educational Series, and the Adopt-the-River Programs with funding from the Community Foundation for Greater New Haven and the CT DEP through the US EPA NPS grant under Section 3.19 of the Clean Water Act. Written by George T. Logan & Sigrun N. Gadwa. Available from ***QRWA***, 99 Colony Street, Meriden, CT 06418 (203-237-2237) for $8.00 ($5.00 for QRWA members and students).