

SECTION 5: BIOLOGICAL DATA EVALUATION: MACROINVERTEBRATES

Macroinvertebrates have been widely used nationwide for many years in pollution studies involving flowing waters. At the Ohio EPA, macroinvertebrate communities have been collected and analyzed since the Agency's inception in 1973 in an effort to provide biological data to be used in the water quality monitoring process. To date, data has been collected at least one time from over 1500 locations displaying a wide variety of water quality conditions within the state.

Aquatic macroinvertebrates are animals without backbones that are large enough to be seen by the unaided eye, can be retained by a U.S. Standard #30 mesh seive (0.595 mm openings), and live at least part of their life cycles within or upon available substrates in a waterbody. Stream macroinvertebrates include organisms such as crayfish, snails, clams, aquatic worms, and, by far the most predominant, larval forms and some adults of several insect orders. As a group, they have a number of characteristics that make them useful as indicators of environmental quality:

- 1) they form permanent, relatively immobile stream communities;
- 2) they can be easily collected in large numbers in even the smallest of streams;
- 3) they can be easily sampled at relatively low cost per sample;
- 4) they are quick to react to environmental change;
- 5) they occupy all stream habitats and, even within family and generic groupings, display a wide range of functional feeding preferences (i.e. predators, collectors, shredders, scrapers);
- 6) they inhabit the middle of the aquatic food web and are a major source of food for fish and other aquatic and terrestrial animals; and
- 7) taxonomy has developed in recent years to the point where species level identifications of many larval forms are available along with much environmental and pollution tolerance information.

Species composition and community structure of stream macroinvertebrates are determined by environmental factors that have existed throughout the life spans of the organisms. Consequently, most types of environmental disturbance, whether long or short term, can alter the existing community structure. The duration and magnitude of community alterations depend upon the duration and severity of the environmental change.

Evaluations using macroinvertebrates are based on the fact that characteristic assemblages of these organisms occur in waters of varying physical and chemical properties. In streams of high water quality and suitable habitat,

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assemblages of these organisms occur in waters of varying physical and chemical properties. In streams of high water quality and suitable habitat, a stable, well-balanced macroinvertebrate community usually exists. The organisms in these areas are usually larval forms of predominantly pollution sensitive insect groups such as stoneflies, mayflies, and caddisflies. The most pollution tolerant groups such as sludgeworms, pulmonate snails, and many types of larval dipteran insects (i.e. bloodworms) are often represented by a few species in low numbers. When environmental quality is adversely impacted, the sensitive groups decline or are eliminated and the few tolerant organisms present greatly increase in number. All types of organisms may be absent under extreme toxic conditions.

Invertebrate Community Index (ICI)

The principle measure of overall macroinvertebrate community condition used by the Ohio EPA is the Invertebrate Community Index (ICI), a measurement derived inhouse from the wealth of information collected over the years. The ICI is a modification of the Index of Biotic Integrity (IBI) for fish developed by Karr (1981) and explained in detail in Section 4 of this document. The ICI consists of ten structural and functional community metrics, each with four scoring categories of 6,4,2, and 0 points (Table 5-1). The point system generally evaluates a sample against the database of relatively undisturbed reference sites (Figure 2-3, Appendix A-3). Six points will be scored if a given metric has a value comparable to those of exceptional stream communities, 4 points for those metric values characteristic of more typical good communities, 2 points for metric values slightly deviating from the expected range of good values, and 0 points for metric values strongly deviating from the expected range of good values. The summation of the individual metric scores (determined by the relevant attributes of an invertebrate sample with some consideration given to stream drainage area) results in the ICI value. Four scoring categories were chosen because of the historical use by the Ohio EPA of four levels of biological community condition (i.e. exceptional, good, fair, poor) a situation which (as defined above) is reflected by the metric score of a sample. The scoring categories were calibrated using data from the 232 reference sites. To determine the 6,4,2, and 0 values for each ICI metric, the reference site database was plotted against drainage area. Each metric was visually examined to determine if any relationship existed with drainage area. When it was decided if a direct, inverse, or no relationship existed, the appropriate 95% line was estimated and the area beneath quadrisected as determined by the distribution of the reference points. Some percent abundance and taxa richness categories were not quadrisected since the data points showed a tendency to clump at or near zero. In these situations, a quadripartite method was used where one of the four scoring categories included zero values only, and, in two cases, the remaining scoring categories were delineated by an equal division of the reference data points.

The decision to use the ten metrics listed was determined by analyzing the process by which Ohio EPA staff biologists judge the quality of a macroinvertebrate sample. In effect, the index quantified a more subjective,

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narrative approach that was used previously (described in DeShon et al. 1980). The end product was a single number to evaluate biological condition that has incorporated into it ten measurements that, with various degrees of effectiveness, can and have often been used to accomplish this task individually. It was thought that, used as a set, these metrics would minimize the weaknesses and drawbacks each has separately. Mostly structural rather than functional components were used because of their accepted historical use, simpler derivation, and ease of interpretation. Metrics 1-9 are all generated from the artificial substrate sample data while Metric 10 is based on the qualitative sample data only.

Metric 1. Total Number of Taxa

The plot of the total taxa metric vs. drainage area is depicted in Figure 5-1. Taxa richness has historically been a key component in most all evaluations of macroinvertebrate integrity. The underlying reason is the basic ecological principle that healthy, stable biological communities have high species richness and diversity. As can be seen by the scatterplot the total number of taxa tends to decrease in the larger rivers. This can be explained by the stream continuum concept (Cummins 1975) which predicts fewer species in larger rivers due to changes in organic inputs and plant growth. Another possibility is that even the best, larger Ohio rivers with reference sites have some cultural degradation.

Metric 2. Number of Mayfly Taxa

Mayflies are an important component of an undisturbed stream macroinvertebrate fauna. As a group, they are decidedly pollution sensitive and are often first to disappear with the onset of perturbation. Thus, they are a good indicator of ambient conditions. The plot of reference site mayfly taxa vs. drainage area is depicted in Figure 5-2. The general trend in mayfly diversity reflects highest variety of types in intermediate size streams with slight decreased diversity in the smaller and larger drainages. This is probably a result of the transitional nature of the intermediate streams and the corresponding increased variety of macrohabitat, microhabitat, and food sources. In effect, environmental conditions are highly diverse and support a mayfly fauna transitional between the smaller Ohio streams (predominated by shredders and collectors) and the larger Ohio rivers (predominated by collectors and grazers).

Metric 3. Number of Caddisfly Taxa

Caddisflies are often a predominant component of the macroinvertebrate fauna in larger, relatively unimpacted Ohio streams and rivers. Though tending to be a little more pollution tolerant as a group than mayflies, they display a wide range of tolerance among types. Notwithstanding, however, few can tolerate heavy pollutional stress and, as such, can be good indicators of environmental conditions. The distribution of reference site caddisfly taxa vs. drainage area shows a clear, increasing trend with stream size (Figure 5-3). This can be explained by the predominance in Ohio of net spinning, filter feeding caddisflies of the families Hydropsychidae, Polycentropodidae, and Philopotamidae and micro-caddisflies of the family Hydroptilidae. Habitat preferences of the filter feeders are streams with abundant suspended organic matter while the micro-caddisflies feed mainly on periphytic diatoms and filamentous algae. These environmental conditions are best met in the larger streams and rivers where import of fine particulate organic matter is maximized and plant growth optimal due to availability of finer sediments and more open canopies. As can be seen in the figure, for drainages less than 600 square miles, zero scores occur only when no caddisfly taxa are present. For

drainages greater than 600 square miles, at least two taxa must be present to score other than zero.

Metric 4. Number of Dipteran Taxa

Of all major aquatic invertebrate groups, dipterans, especially midges of the family Chironomidae, have the greatest faunal diversity and display the greatest range of pollutional tolerances. They are usually the major component of an invertebrate collection using Ohio EPA methodology and, under heavy pollutional stress, can often be the only insect collected and, at the same time, be the predominant macroinvertebrate group. Larval taxonomy has improved greatly for the group and clear patterns of organism assemblages have become distinct under water quality conditions ranging from the pristine to the heavily organic and toxic. The fact that they do not usually disappear under severe pollutional stress makes them especially valuable in evaluating water quality. The distribution of dipteran taxa vs. drainage area is shown in Figure 5-4. A clear, inverse relationship with larger drainages (>100 sq miles) is apparent. In the larger rivers, there is a tendency towards increased populations of fewer dipteran taxa. This is probably the result of abundant food supplies but fewer functional feeding groups as habitat conditions become more monotonous.

Metric 5. Percent Mayflies

As with number of mayfly taxa, the percent abundance of mayflies in a sample can react strongly and rapidly to often minor environmental disturbances. Though much more reference site variability exists in this metric compared with the taxa metric, there is a strong relationship with water quality. As can be seen by Figure 5-5, the range of abundances in the relatively unimpacted reference site database varies from near zero to greater than 80 percent. However, data from slightly degraded (fair) and severely degraded (poor) stream communities in Ohio indicate that mayfly abundance is reduced considerably under slight impact and is essentially nonexistent under severe impact. Thus, it was felt that even a few mayflies in low abundance should score at least minimally. Therefore, only those samples with no mayflies will score zero for the metric. Scoring categories also reflect the observation that no relationship exists with drainage area.

Metric 6. Percent Caddisflies

As with number of caddisfly taxa, percent abundance of caddisflies is strongly related to stream size (Figure 5-6). Again, optimal habitat and availability of appropriate food type seem to be the main considerations for large populations of caddisflies. As can be seen in the figure, the caddisflies can make up a significant portion of the macroinvertebrate community, often exceeding 25 percent of the organisms collected. However, they are just as likely to be found in quite low numbers, at times less than 1 percent. Because of their general position as an intermediately pollution tolerant group between the mayflies and dipterans and because they disappear rapidly under environmental stress, zero scores are restricted to those sites less

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than 600 square miles where no caddisflies are collected. At sites greater than 600 square miles, it is felt that appropriate habitat conditions are much more likely to exist and, therefore, caddisflies should be present in at least minimal numbers to score greater than zero.

Metric 7. Percent Tanytarsini Midges

The tanytarsini midges are a tribe of the chironomid subfamily Chironominae. The larvae are generally burrowers or clingers, and many species build cases out of sand, silt, and/or detritus. Many species feed on microorganisms and detritus through filtering and gathering though a few are scrapers. Eleven genera and up to 140 species occur in North America, although only 8 genera and 21 distinct taxa have been collected in Ohio. In the relatively unimpacted Ohio reference sites, they are most often the predominant midge group, often exceeding 50 percent of the total number of organisms collected. They also appear to be relatively pollution sensitive and often disappear or decline under even minor pollutional stress. As can be seen in Figure 5-7, there is apparently no drainage area effect on their abundance. Because of their relative intolerance to environmental disturbance, zero scores only occur when no tanytarsini midges are present.

Metric 8. Percent Other Diptera and Non-Insects

This metric includes the community percentage of all dipterans (excluding the midge tribe Tanytarsini) and other non-insect invertebrates such as aquatic worms, flatworms, scuds, aquatic sow bugs, freshwater hydras, and snails. This metric is one of two negative metrics of the ICI. Taxa in these groups of macroinvertebrates, though often present as part of a healthy stream community, are those that generally tend to become predominant under adverse water quality conditions. In many cases, even under minor influences, these organisms will comprise over 90 percent of the individuals collected in an invertebrate sample. Figure 5-8 depicts the distribution of reference site data for the metric. As indicated, reference site percentages are inversely related to stream size. However, this relationship does not seem to hold for impacted situations; under these circumstances, other dipterans and non-insects usually predominate as a high percentage regardless of stream size. In cases where conditions are so severe that no organisms are collected (in effect, 0 percent other dipterans and non-insects), the metric should score a zero.

Metric 9. Percent Tolerant Organisms

Values for this metric are generated using the list of organisms provided in Table 5-2. The list includes those organisms in Ohio that appear to be extremely pollution tolerant and tend to predominate in cases of severe perturbation. The list includes organisms tolerant to organic degradation as well as some Ohio taxa found to resist toxic impact, so the metric should be a reasonable measurement of community tolerance under both types of degradation. This is a desirable difference over other established measurements of community tolerance (i.e. Hilsenhoff's BI) that were developed

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to reflect one type of pollution or the other. Like Metric 8, this is a negative metric and, as such, complete absence of organisms in a sample should score a zero for the metric. Figure 5-9 depicts the reference site tolerant organism percentages vs. drainage area. A strong inverse relationship with drainage area exists. For drainages greater than 1000 square miles, the percent of tolerant organisms found at reference sites becomes so low that the scoring categories are quite restrictive. In fact, at a number of the reference sites, none or less than 1 percent of these organisms were present. However, as with Metric 8, drainage area tends to have little effect when pollutional disturbances are prevalent. Sites with minor or severe degradation can have large populations of these organisms regardless of stream size.

Metric 10. Qualitative EPT Taxa

This metric is the one ICI metric that is generated by the qualitative sample taken in conjunction with the artificial substrate sampling. Since the qualitative sampling utilizes a substrate dependent method, that is, a method affected by the kinds of natural substrates available in the sampling area, the metric is a measurement of habitat quality as well as of habitat types other than the run habitat where artificial substrate sampling occurs. The metric consists of the taxa richness of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). Since stoneflies are relatively uncommon in summer collections in Ohio, the metric is mostly dependent on the kinds of mayflies and caddisflies found. The depiction of qualitative EPT taxa vs. drainage area (Figure 5-10) reflects a trend similar to Metric 2, the number of mayfly taxa. Again, it is thought that this trend is a result of greater habitat and food type variety in the intermediate sized streams transitional between small streams and large rivers.