Stream Ecology Basics and Sampling Training Guide

This manual is intended to supplement volunteer monitoring efforts using the protocol developed for western NC, by Clean Water of North Carolina.

Monitoring streams and rivers yields a greater understanding of processes and patterns in the watersheds where people live, play and work. Monitoring programs can help to build local awareness of water quality issues and may play an important role in decision making by private agencies and local, state and federal governments. Volunteer monitoring is an excellent opportunity to teach the scientific method, as well as natural history.

Stream monitoring is an effort to better understand how streams are affected by human and natural processes. This requires some background information about streams in general and in western NC specifically. All streams are unique, yet they all share similar features and properties. It is the similarity between streams that enables us to make comparisons between streams and draw general inferences about stream health and water quality.

This protocol requires a bit more detail in identifying aquatic insects. No microscopes are necessary, however, and complicated terminology can be kept to a minimum. Volunteers who monitor streams a few times will learn a great deal about the streams they visit, in terms of 'water quality' and stream order. Additionally, this knowledge can be helpful to fly-fishers who may tie their own flies for their personal favorite streams. Learning more about the insects that are always crawling around the bottom of our local streams (even in winter, even in night, an endless struggle to survive and reproduce in a hostile environment) may at the very least provide a different perspective with which to appreciate the streams and watersheds in which a person might live or work.

I. Stream Definitions and Background

In this text, the term *stream* is used to describe flowing waters (or *lotic* habitats). This includes rivers, creeks, branches and runs. When streams are impounded in a lake or reservoir (*lentic* habitats), the biological, chemical and physical characteristics of the stream often change significantly. Here we will only discuss lotic (flowing water) habitats (although habitats in extremely large rivers may have lentic properties).

Streams remove inorganic and organic materials from the landscape by water transport. This process contributes to the shape and dimensions of the stream itself. The geologic history and characteristics underneath the watershed also strongly affect the *morphology* of the stream. For example, streams draining to the south of the Blue Ridge Escarpment (Continental Divide) in Henderson, Transylvania, Jackson and Macon counties are extremely steep with numerous waterfalls. Streams north of this continental divide do not generally share the same morphology. The difference is primarily geological: the result is that streams draining to the south leave the mountains immediately, descending a steep escarpment, while streams draining to the north have a much lower *gradient* and leave the mountains much more slowly. These types of factors can have dramatic effects on the shape, features and size of streams, as well as the organisms that can and do inhabit them.

Watersheds are geographical areas in which the streams all drain to one body of water (whether a stream or lake or other water body). Watershed, as a term itself, has no implied size or shape and can refer to < 1 km^2 areas, or the entire river systems (for example, the French Broad River watershed, encompassing parts of NC and TN). Watersheds are often called *basins* at this large geographic scale. *Stream order* is a hierarchical system of describing streams, beginning by identifying the *headwaters* of a stream as *first-order* (see Figure 1). Streams which flow into a headwaters stream are called *tributaries*. When two first-order streams meet, the stream is then *second-order.* Below the confluence of two second-order streams, a stream is *third-order*, and so on. When a first-order stream meets a second-order stream, the designation does not change. Some biologists have suggested that biological and ecological stream processes (like the types and numbers of fish or macroinvertebrates) can be closely related to stream order.

White settlers began relocating and straightening streams from their 'natural' (pre-settlement) positions immediately after settlement, a process that still occurs today (although now regulated under relevant state and federal laws). The reasons given for relocating stream channels include draining agricultural land, mosquito control, dam construction, road building and aesthetic reasons. 'Natural' stream channels are rarely straight, but follow a pattern of bends and *meanders.* When channels are straightened, an increase in *particle transport* usually follows, along with changes in the *erosion* and *deposition* processes occurring in the stream. This often results in channels *incising* (or cutting into) the stream bed, and a general lowering of the *water table* in the immediate area. Corresponding changes in fish and macroinvertebrate populations can follow in incised streams.

Habitats for aquatic organisms can generally be described in two categories: *depositional* and *erosional*. Depositional habitats are places in the stream where sediment and organic materials are deposited by currents. Erosional habitats are places where stream currents remove these materials. Depositional habitats might include the bottom of deep pools, swamps, sand bars and marshes. A few examples of erosional habitats are waterfalls, seeps, riffles and scour pools. A stream is essentially a longitudinal pattern of depositional and erosional habitats. See Figure 4 for an example of adjacent erosional and depositional habitats.

Streams and Watersheds are Ecosystems

Streams in forested landscapes across the world show general similarities in *ecosystem* function. Small to medium sized Western NC streams follow this same pattern, which is a net flow of energy and materials from the terrestrial landscape to the stream. This means that most of the energy available for organisms living in these ecosystems comes in the form of leaves and woody debris. Streams that drain forested areas generally are habitat for many organisms that utilize forest materials for food. In small streams (and often continuing to larger streams and rivers), leaves from the surrounding forest and *riparian zones* provide the energy for the *benthic macroinvertebrate* community. In larger rivers where sunshine reaches the stream bottom easily (like the French Broad River in Asheville), instream photosynthesis begins to play an important role.

As soon as leaves fall from a tree, they begin decomposing. This process is hastened by the wetting of the leaf into a spring or stream. Fungi and bacteria soon colonize the leaf and begin softening the hard materials in the leaf, preparing it for ingestion by macroinvertebrates. Leaves and wood enter all streams of all sizes, but small streams have many more leaves per unit area, and this is where most of the aquatic decomposition occurs.

The annual input of woody debris and leaves is an extremely important stream habitat feature in the Southern Appalachians. This material provides the energy base for many stream ecosystems. Healthy stream communities efficiently utilize this energy, transforming leaves and wood into tiny particles, mayflies, bats and speckled trout, among other things. Leaves are consumed by microbes, which are eaten by shredder organisms. Feces and small left over particles of food in turn are collected by other types of organisms (collectors and filterers). Predators are present in nearly all ecosystems on earth and aquatic systems are no exception. Adult aquatic insects are vulnerable to predation by other insects, fish, mammals, birds, reptiles and amphibians. In this fashion, streams also provide energy resources to the adjacent terrestrial ecosystems.

Certain kinds of disturbance may disrupt this linkage between the surrounding vegetation and stream production. In these instances, we might find very few leaves in the stream, or we may find no insects in the leaves that are present. This can represent a substantial loss of biomass from an insect community, which may have effects on the fish populations which rely on the insect community for food. Considering *trophic* richness and/or diversity of stream samples may be as informative as other measures (*EPT* or *taxa richness*), especially when certain trophic groups are present in misproportional amounts. The relative proportions of insect trophic groups (or feeding guilds) can reflect the relative proportions of food resources for each group. There can be large differences in the insects found in large and small streams, that are not related to tolerance or water quality or point discharges, but more directly to the size the stream or watershed.

Small streams are often shaded from direct sunlight, inhibiting *primary production* from algae or *macrophytes* (except in the winter, when leaves do not prohibit sunlight from striking the stream). Bacteria and fungus *decompose* the leaves and wood entering the stream from the forest, and in turn are eaten by *shredder* organisms, which is often a dominant trophic group in these habitats. The smaller particles (*detritus*) shredded by the insects, and also their feces, in turn become food for other organisms downstream (*collector-gatherers* or *filter-feeders*). Some benthic macroinvertebrates are very specific about the size of the particles which they feed upon and may ignore food outside of a particular range of sizes. Some biologists have suggested that this allows the benthic macroinvertebrate community to use the food resource more efficiently (*resource partitioning*).

As streams grow larger and wider, downstream of *headwaters* and small *tributaries*, sunlight plays a more important role in the stream; leaves and woody debris lessen in significance. Organisms that use *detritus* food sources make room for organisms that use the increased *primary production* in the sunny large rivers (*scrapers* such as snails and some mayflies obtain their food by removing algae from underwater surfaces and are more abundant in higher order stream habitats). *Predators* can be found in small and large rivers (and nearly any other habitat). The amounts of nutrients in the water play an important role in controlling the amount of *primary production* in streams and rivers. Nutrient pollution can cause the growth of algae that are normally kept in check by other factors. This may be evident by large mats of blue-green algae or fish kills (sometimes a result of biological oxygen demand from decaying algae).

There are seasonal differences in *benthic macroinvertebrate* communities. Many organisms have annual life cycles, but some (such as dragonflies and hellgrammites) may spend two or three years in the stream. Many *shredder* populations are largest during times when leaf and woody materials are most abundant (late winter and early spring). Warm temperatures in late spring and summer are used by many aquatic insects for mating and reproduction. During these times, some insects may be difficult or impossible to collect (for example, some mayfly populations hatch and mate in a span of a few days). Extremely small (young) insects are difficult to collect and identify. In general, spring sampling times should yield the highest *taxa* or *EPT richness* of the year. Late summer sampling times will probably yield the lowest richness estimates, especially in smaller streams. Even so, you may sample aquatic macroinvertebrates during any time of the year.

Shredder organisms consume leaves, twigs and other large pieces of *detritus*. Biologists have shown that, at least in some instances, these animals may gain as much nutrition from the fungal and bacterial colonies in the detritus as from the wood or leaf itself. Feces and undigested detritus are then in turn food for other organisms, or dissolve into the water. The particles of leaves are now called *CPOM (coarse particulate organic matter)*. The CPOM is readily transported by the stream to pools, leaf-packs and other depositional areas.

Collector-gatherer organisms search benthic areas for this material. Many different types of insects and crustaceans take advantage of this plentiful food resource. As CPOM is utilized by collector-gatherers, the particles grow smaller and smaller. When particles are smaller than 1 mm, then they are termed *FPOM (fine particulate organic matter)*. These particles are much more easily transported by the stream and are food for another group of organisms.

Filter-collectors are organisms that strain FPOM from the flowing water of the stream itself. Many members of the net-spinning family of caddisflies (Hydropsychidae) build intricate silken nets and tubes to collect FPOM from the current. In the appropriate habitats, you may observe the nets, anchored to rocks in the current. These caddisflies ‘graze’ their nets, consuming all the FPOM that has collected there (and sometimes algae or micro-organisms). Caddisflies in some ecosystems appear to share or *partition* the FPOM resource; several different net spinning *taxa* may be in the same habitat, but each filtering a different range of particle sizes from the current. A few organisms have brushes of hairs (*setae*) on their legs that collect FPOM, still others actively pump water through silken tubes to filter out FPOM.

Scraper-collectors are the 'cows' of the stream ecosystem. While present in nearly all lotic and lentic systems, scrapers will be most common in larger streams and rivers, where streams receive direct sunlight in the summer. Every available surface in the stream (whether stone, log, leaf, refrigerator, snail shell, pop bottle or boat bottom) is potentially colonizable by algae. Algae colonies are colonized by bacterial and fungal colonies, which also collect FPOM. The diverse matrix of readily digestible organic material is sometimes called *aufwuchs*, which is a German term meaning 'living on'. This material, no matter what you call it, is the preferred food of *scraper-collectors*. A few examples of scrapers include snails, some caddisflies, waterpennies and a few mayflies (trout anglers might know the mayflies by the names of their adult imitations: March Brown, Quill Gordon, Light and Dark Cahill flies are all imitations of the mayfly genera *Epeorus* and *Stenonema*).

The last major *trophic group* of stream organisms that we will consider here are the *predators*. Some of these organisms are only predatory in the last stages of their larval life, but others (such as the dragonflies and damselflies, or *Odonata*) may be predators their entire lives, even as adults. Predators are at the 'top' of the food chain, and can limit the abundance and distribution of prey organisms (although some predators are in turn prey for other predators, such as fish or birds). A few insect larvae (e.g., Rhyacophilid caddisflies and Perlid stoneflies) may actively seek their prey, crawling around on the stream bottom and attacking smaller insects. Others (the dragonflies and damselflies) have adopted 'sit and wait' strategies and allow the food to come from them. During summer, you may observe large dragonfly larvae sitting and waiting near the bank or in shallow depositional areas, lightly covered by silt and FPOM and a few centimeters of water.

In general, the relative abundance of these various groups is directly dependent upon the abundance of the food resources and habitats. In small headwater or low-order streams, shredder organisms should be in greater numbers or *biomass* than scraper organisms. Filter-feeders should be most prevalent in mid-sized rivers, from third to fifth order. Interestingly, the ratio of predators to other organisms is much more stable, when comparing small streams to large streams (nearly all ecosystems have predator species). This protocol works from the suggestion that these groups of insects may be used as indicators of certain kinds of stream disturbance or pollution.

III. The science of sampling

A good understanding of a few of the issues behind 'sampling' streams is necessary for stream monitoring. Since streams and rivers can cover huge geographic areas, we must by necessity only sample a few locations (points on a map). Even in these locations, we can never be sure if we have collected all of the organisms present in the stream. A trip to the stream to turn over a few rocks will quickly convince you that a complete count of macroinvertebrates is quite impossible.

Since we can't go out and collect every organism every time we sample, our best option is to always apply the same amount of effort to sampling, every time we sample. This means that we are *standardizing* our collection efforts, so that we can compare our results. Biological systems are extremely complex, and our understanding of their functions vary with an endless number of *parameters* and spatial and temporal scales. Thus, standardization is perhaps the most important concept to grasp before beginning a stream monitoring program, and an important tenet in scientific inquiry. We must reduce as much possible bias from our methods to provide the highest quality information. All samples must be collected in the same fashion and within the specified conditions in a standardized operating procedure.

We seek to standardize our sampling effort so that streams are always sampled the same way. The *effort* may be defined as a combination of ‘intensity of sampling’ and ‘scale of sampling’. In our stream monitoring example, we sample 15 ft^2 of riffle for the duration of one minute. This procedure should always be followed, covering the same area and the same period of time. Covering a smaller area, or shorter period of time, may diminish the numbers and types of organisms recovered in the sample. Covering too large an area, or for too long a time, may recover too many organisms. Either error will make analysis and comparison of the results to other samples very difficult and likely impossible.

Another potential confounding factor is in the identification of macroinvertebrates. Misidentification of shredder stoneflies as predators, for example, may cause problems in the computation of our *metrics* for stream monitoring. Careful use of keys and pictures to properly identify macroinvertebrates is a crucial component of a successful stream monitoring program. Familiarity with the subject material (i.e., learn your bugs) will greatly reduce time spent in the field identifying insects.

Any sampling scheme will yield several classes of information which may be used to compute *metrics*. A metric is a descriptive number that yields some form of generalization about the data collected (see Appendix). The most commonly used metric is *taxa richness*. This is simply the number of different ‘kinds’ or ‘types’ of organisms in the sample. Since we will not be fully identifying macroinvertebrates to the species level, we can not estimate *species richness*.

Some macroinvertebrates are more sensitive to certain forms of pollution than others. We will take advantage of this distinction by comparing the numbers of organisms found in three different categories (intolerant, somewhat tolerant and tolerant). Various stream monitoring protocols use some measure of *tolerance* in their analyses, but some information is lost during the process when macroinvertebrates are not identified to species. This limits the usefulness of tolerance categories for making strong inferences from our data. Even so, we can still gain useful information from these types of metrics, especially if we can use family level identifications. Tolerance metrics which use order levels of classifications will suffice for making general statements about the quality of the macroinvertebrate community.

We are interested in sampling two distinct habitats: *riffles* and *leafpacks*. Riffles are excellent habitat for many different benthic macroinvertebrates, since they have high oxygen levels and a diversity of rocks and gravel to collect food and provide cover. Riffles form where materials (sediment, detritus, etc) have been deposited by high water levels. The proper riffle for our sampling is shallow enough to wade safely and has rocks and gravel that are easily displaced with your feet (see Figures 2 and 3). Extremely fast water is often poor macroinvertebrate habitat anyway, occupied only by a few organisms with specialized adaptations to living in this extreme environment.

Leaf packs may occur in both *erosional* and *depositional* habitats. Figure 3 is a fine example of an erosional habitat, with white raging water and large stone bed. Leaf packs are unlikely to occur in this type of habitat, but are visible in Figure 2, which is also an erosional habitat. Each habitat has unique properties that influence the organisms found in each. Deep pools may have deep deposits of leaf litter extending many inches deep. The resulting organic decay can locally reduce dissolved oxygen (BOD), so these areas are not good places to collect leaf packs for the sample (although some organisms use these habitats). The proper leaf pack for our sampling will be submerged under moving water and not in deep still water **(see picture)**. This may be found along the bank of the stream or in the middle of the current. Avoid fresh leaves, they do not have the proper bacterial and fungal populations to provide tasty food for *shredder* organisms. Brown or black leaves with visible signs of decomposition (holes, etc.) are our target habitat.

The kick net sample is easily biased by poor procedure. Make sure that the bottom of the net is weighted to the stream bottom with any small rocks or stones handy nearby. Kicking areas that are outside of the area flowing into the net is unproductive, since the kick net won’t be receiving any of these materials. The top of the kick net should be bowed inward slightly (see Figure 5). No water should be flowing over the top of the net, at any time.

Glossary

Aufwuchs- German derived word to describe the entire community of microscopic organisms attached to any substrate (includes algae, bacteria, fungi, protozoa and small metazoans).

Biomass- The collective total mass of an organism, population, community or ecosystem. Changes in biomass over time can be used to describe changes in management strategies (for fish or wildlife) or natural variability of population sizes (for rare species management).

Collector-gatherer- A feeding strategy employed by many aquatic insects and other organisms. Food is collected by actively searching and manually collecting food particles, often on the bottom of the stream.

CPOM- Coarse Particulate Organic Matter, can include small bits of wood or feces, all the way to fallen trees (these are often called Large Woody Debris). An important instream food resource in most streams, CPOM is utilized in many different ways by stream macroinvertebrates.

Depositional- An area in the stream where material is deposited by slowing stream currents. Whether an area is depositional or erosional is dependent upon the local shape of the stream, as well as the amount of water in the river. Floods can change the pattern of depositional zones in a stream or river.

Detritus- a general term for dead organic matter. Includes both CPOM, FPOM and dissolved organic matter (DOM).

Ecosystem- a hypothetical ‘system’ used to describe patterns in the various ways that living and non living things interact. Common uses of ecosystem ideas include energy transfer or production by plants and animals, the structure of plant communities and aquatic communities, and the estimation of changes in greenhouse gas emissions by tropical deforestation.

Effort- a numerical value that represents a standardized amount of effort directed at sampling organisms (can include area or time variables). One example is the prescribed use of two people in the visual collection portion of the macroinvertebrate protocol. Collections made with three or with one person are not comparable to collections made with two, so effort must be restricted to a two-person sample.

Erosional- the counterpart to depositional, described above, erosional areas are locations in or along the stream where materials are carried away from a resting position on the bottom (changes in water level from floods or droughts can affect the erosional capacity of a stream).

Filter-collector- organisms that strain food particles (often FPOM) from stream currents. Some animals actively pump water through a filter, others build elaborate nets and tubes that collect material constantly.

FPOM- Fine Particulate Organic Matter, a major component of the food resource for stream organisms. The difference between FPOM and CPOM is only in the size definition, usually FPOM is less than 1 mm wide.

Gradient- The slope of a stream (how much the stream drops in a specified length). Some organisms prefer high gradient habitats, sometimes steep gradients can act to prevent other organisms from reaching suitable habitats (especially fish).

Headwaters- The most upstream segments of streams. In this area streams are just beginning to form and may be very small (even intermittently leaving the ground surface and traveling through subterranean passageways). The headwaters of a stream may also be used to refer to a small watershed.

Incising- Increased discharge in a stream channel can cause erosion to bed materials, lowering the stream bottom and often cutting a channel in the stream course.

Lentic- 'Standing' water, including puddles, ponds, reservoirs, oceans and empty tires that have collected water.

Lotic- 'Running' water, including spray cliff and littoral communities, as well as streams rivers and point discharges.

Meander- Streams tend to 'bend' and wander across the landscape, over time. This is mainly because running water must dissipate energy whenever possible, and the S-shaped curves of meanders do this surprisingly well within the confines of the river valley. Connecting streams across meanders (stream straightening) was a common land management practice in WNC until relatively recently.

Metrics- These numbers are used to summarize information (data), in this example stream sampling data are summarized into several metrics which can yield new information not readily visible from the data sheet.

Morphology- The physical description or character of a stream channel (can be used at multiple scales). For example, the French Broad River basin has a distinct morphology that is quite different than the Little Tennessee (FB begins flowing east, then turns north, draining a large plateau; LT flows north originally, then turns west and accepts the drainage from several large rivers immediately).

Parameters- Measurable attributes that may be used to explain biological systems (for example, acid rain deposition in a forest soil is a measurable parameter).

Particle transport- the primary function of streams across the landscape. Streams move particles (organic and non organic) from headwaters to the ocean. This is measurable parameter for stream of all sizes.

Partition- Communities of aquatic macroinvertebrates have multiple members utilizing the same food resource, sometimes these organisms select food resources within size ranges to avoid competing with other similarly feeding organisms (filter feeding Hydropsychid caddisflies are a great example of resource partitioning).

Predator- An organism which primarily obtains energy from consuming other living non-plant organisms.

Scraper-collector- Benthic macroinvertebrates which actively remove microscopic plants (and the rest of the *aufwuchs* community) from wetted surfaces. Scrapers usually have body parts adapted for food collection; Heptageniid mayflies have body shapes that allow them to stay flattened to rocks in high current velocities.

Setae- Small hair like structures on insects that may be used for sensory purposes, locomotion or feeding.

Shredder- An organism which consumes plant material, often by chewing. These organisms often have microorganisms in their gut which aid in the decomposition of woody materials.

Species richness- The total number of species collected in a sample or in a community.

Standardizing- A scientific method that attempts to insure that samples are collected and analyzed in the same fashion every time. This includes using a set of procedures agreed upon before sampling.

Stream order- A classification system based on the arrangement of tributaries in a watershed.

Taxa richness- The total number of taxa collected in a sample or in a community. Taxa is a more general method of classification than species, and can be used to designate any taxonomic level desired by the user (whether species, genera, family or order richness).

Tolerance- Generally used to refer to the ability of organisms to withstand pollution 'insults'. Some popular uses of tolerance ideas group organisms into three categories (tolerant, mildly tolerant, intolerant). There are different types of tolerance, so this concept has a limited application unless linked with the types of pollution that organisms may be exposed to.

Trophic group- Usually used to group organisms into groups based on feeding habits. Common stream macroinvertebrate trophic groups are Scrapers, Collectors, Filterers, Shredders and Predators.

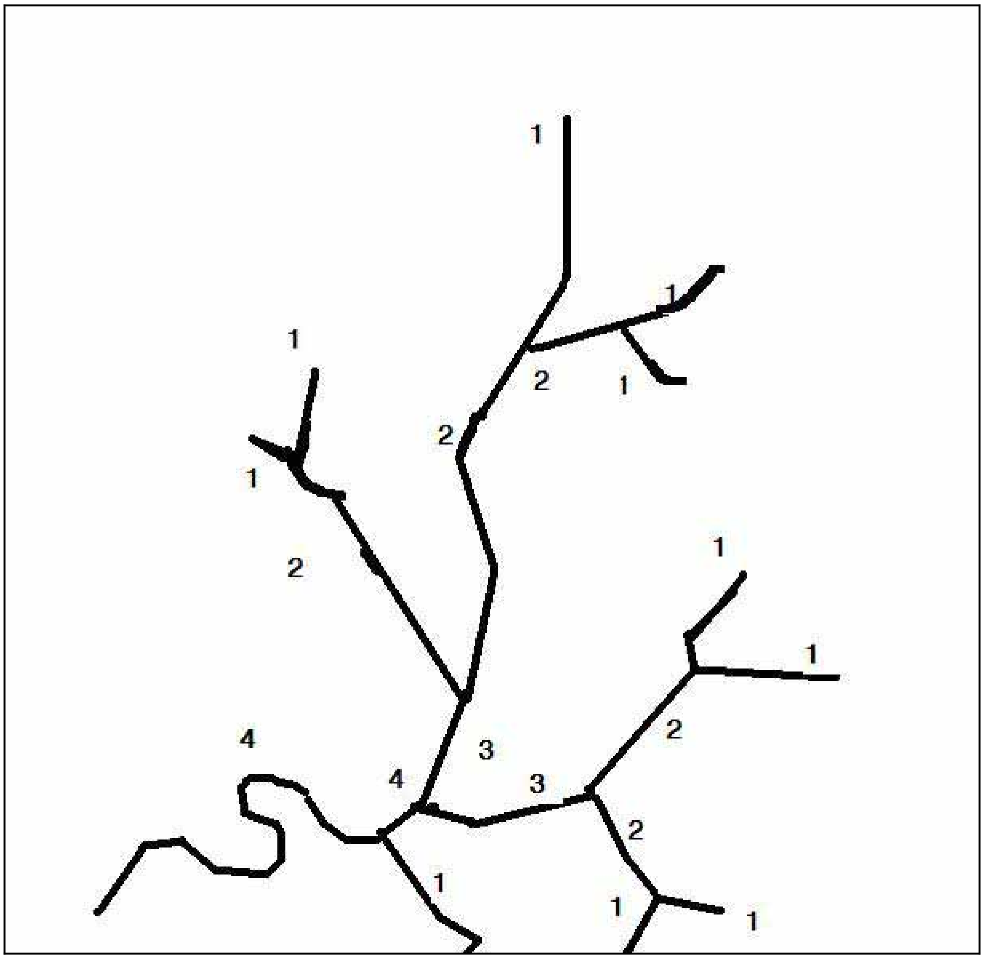


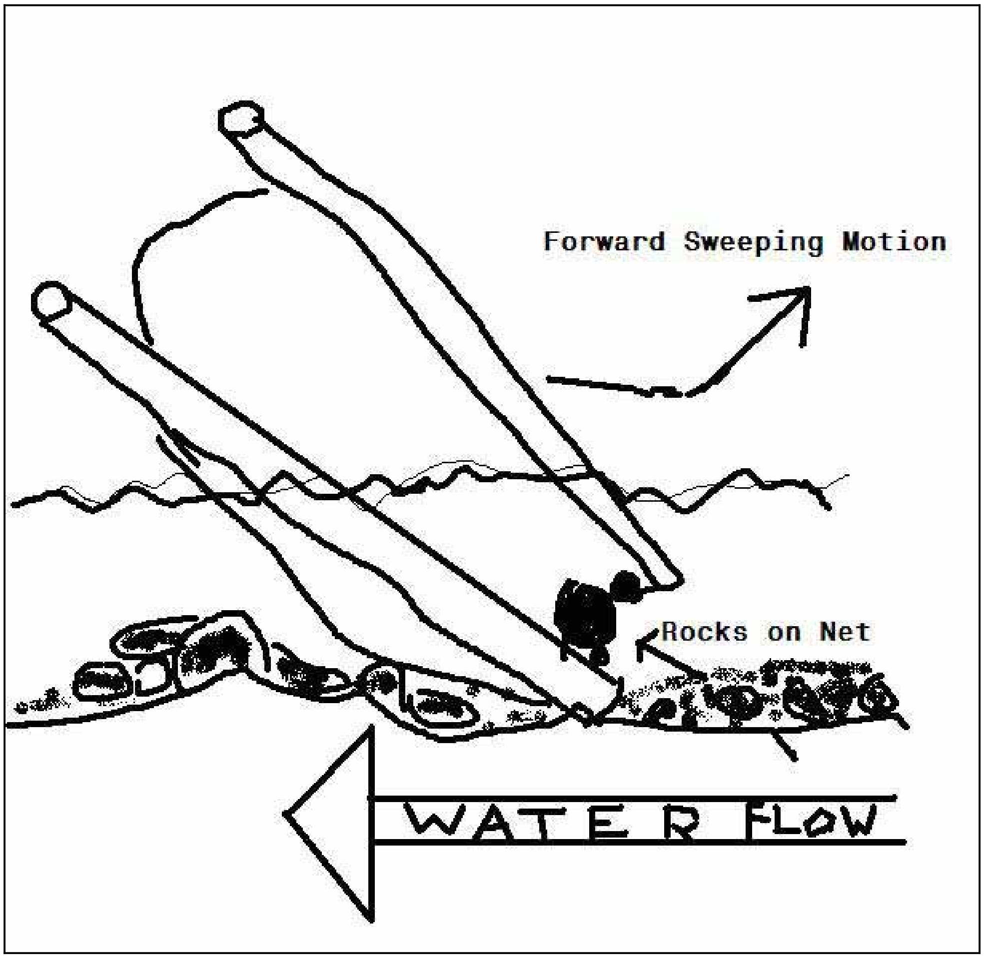
Figure 1 Hypothetical watershed for illustrating Stream Order Rules. Headwater streams and small tributaries are 1st order. At the confluence of two 1st order streams begins a stream of 2nd order. Two 2nd order streams meeting results in a stream of 3rd order, and so on. The addition of a lower order stream does not affect the order of the main channel (as in the 1st order tributary in the fourth order stream illustrated above.

Figure 2 A riffle suitable for stream sampling. This is perhaps as small a stream as you might wish to sample for monitoring reasons (sample nothing smaller), but this stream is more than six feet wide and is actually a fourth order stream. Maps can give you more information about stream order when planning sample sites.

Figure 3 The riffle in the foreground of this picture is too large to safely wade for sampling. The section upstream of the white water (near the black pack) is more appropriate for sampling.

Figure 4 Adjacent erosional and depositional habitats. The waterfall is an erosional habitat feature, in the foreground are deposits of sand transported during floods and increased flows.

Figure 5 Schematic for proper kick net placement and retrieval. Kick net is facing upstream to the right. Note the bow in the net, this is important for creating a depositional area where insects can be accumulated. Weighting the net with rocks ensures that the net remains on the bottom of the stream. When removing the kicknet from the water, ensure that no water washes over the top of the net. Bring the sides together and slowly bring the net out of the water in a forward sweeping motion.



Metrics for use in Benthic Macroinvertebrate Bioassessments

A. **EPT Taxa Richness:** The number of different kinds of insects from the orders Ephemeroptera, Plecoptera and Trichoptera (mayflies, stoneflies and caddisflies) represented in a sample. Determining species richness is difficult, especially in the field, because of the need to closely identify every individual. Many insects may be found in these orders at a given site, so order richness has a minimal amount of information. Families or trophic (feeding) groups of aquatic insects are a useful grouping category, and many members of families more than superficially resemble each other (morphological and behavioral similarities). Identification past family may require microscopic inspection.

B. **ECO (Izaak Walton) Stream Rating**: The Izaak Walton Rating uses the presence of various macroinvertebrate groups, combined with estimated tolerance values for these groups, to provide an index of water quality. There are four categories of water quality values (outputs): Excellent (score > 22), Good (17-22), Fair (11-16) and Poor (score <11).

C. **VASOS Multimetric Index:** The VASOS index calculates several metrics which are then used to produce an 'unacceptable' or 'unacceptable' ecological condition rating. The six metrics are % EPT (excluding the 'netspinner' caddisflies), % Hydropsychid (netspinner) caddisflies, % lunged snail, % beetle, % Tolerant Organisms and % Non-insects. The VASOS procedure includes the details for using these six metrics to calculate the final index value (unacceptable or unacceptable).

D. **Total Number of Organisms:** This metric is merely a sum of all the benthic macroinvertebrates collected in a sample. Sometimes a sample does not have many organisms for no obvious reason other than there happened to be few macroinvertebrates. This is called 'patchiness', a natural property of many living (plant and animal) communities. This poses a very real problem to the interpretation of any kind of sampling, including stream sampling. We will not attempt to solve this problem here, but the total number of macroinvertebrates collected is an important piece of the larger picture.

E. **Tolerance Metrics:** Several sampling and monitoring schemes assign taxa to classes of pollution tolerance. Three kinds of tolerance class are recognized: intolerant, mildly tolerant and tolerant. Tolerant organisms are often abundant in degraded habitats and environments; even some members of the normally intolerant taxa are tolerant to some types of pollution (particularly some mayflies and caddisflies).

F. **Ecological Metrics:** Placing organisms into one of five feeding categories may provide information about stream ecosystem parameters. Here are some general metrics from a stream ecology textbook and published literature (Merritt and Cummins, 1996; Merritt et al, 2000),

1. Production-Respiration Ratio: calculated as the ratio of 'Scrapers' to 'Filterers' and 'Collectors'. P/R > 0.75 means the stream may be <u>autotrophic</u> (net production of organic matter). P/R<0.75 suggests the stream is <u>heterotrophic</u> (net consumption of organic matter).
2. Allochthonous Input Index: <u>Allochthonous</u> (or 'external') inputs include leaves, twigs and trees. These materials are allochthonous because they are produced outside of the stream (autochthonous materials would be underwater plants, algae and mosses). This index is calculated as the ratio of 'shredders' to 'collectors' and 'filterers'. Heterotrophic systems relying primarily upon allochthonous inputs (shredder streams) will have spring and summer values > 0.25 (autumn and winter values > 0.5).
3. Particulate Organic Matter Transport: Particulate organic matter includes both allochthonous and autochthonous materials. This metric compares the ratio of 'filterers' to 'gatherers', natural values should be > 0.5. Enrichment of streams with FPOM (fine particulate organic matter) may result in benthic storage of these materials, potentially contributing to an increased BOD (biological oxygen demand) and diminished habitat value.
4. Habitat Stability Index: This metric evaluates the availability of stable surfaces and substrates for benthic macroinvertebrate habitat (values should be > 0.5). This index is calculated by the ratio of 'scrapers' and 'filterers' to 'shredders' and 'collectors'
5. Top-Down Control: In some cases we might see that predators are controlling macroinvertebrate distributions. In these instances, a ratio of predators to all other groups would greater than 0.15. Predators that are effective colonizers may potentially limit the colonization of new habitats, particularly at stream restorations or sites with severe natural disturbances where 'natural' communities have been altered or destroyed.