	Advantages	Disadvantages
Multimetric analysis (B-IBI)	• relatively easy to understand how scoring criteria are derived • results can be easily calculated by hand • allows you to think about how particular groups and types of macros respond to increasing human disturbance • easier to incorporate reference streams in future years into the index	• metrics and scoring criteria should be reevaluated before using in a new area or different type of stream (e.g., valley vs. mountain) • does not directly incorporate habitat characteristics • requires judgment-based assignment of scoring criteria that may skew the results if several metrics happen to fall just to one side of the criterion
Multivariate analysis (WOWSA)	• a single model covers an entire region and all the different types of streams in that region • slightly better at discriminating between levels of impact • provides information on taxa that were expected but absent, or not expected but present • incorporates habitat characteristics of the stream	• model development is difficult to understand and more difficult to do • must rely on someone else to run your data through the model • updating the model with recent reference information that represents natural variability

Order list:

Insect Orders	*Non-Insect Groups*
Mayflies (Ephemeroptera)	Water mites, Hydracarina (Acarina)
Stoneflies (Plecoptera)	Scuds, sowbugs, crayfish, and pals (Crustacea)
Caddisflies (Trichoptera)	Snails, limpets, clams, and mussels (Mollusca)
	Aquatic worms (Oligochaeta, Polychaeta)
True flies (Diptera)	Crayfish worms (Branchiobdellida)
Aquatic beetles (Coleoptera)	Leeches (Hirudinea)
Dobsonflies and alderflies (Megaloptera)	Hydroids (Cnidaria)
Aquatic moths (Lepidoptera)	Flatworms (Turbellaria)
Dragonflies and damselflies (Odonata)	Ribbon worms (Nemertea)
Aquatic true bugs (Hemiptera)	Roundworms (Nematoda)
Springtails (Collembola)	Horsehair worms (Nematomorpha)
	Moss animals (Ectoprocta)
incidental adults	Sponges (Porifera)

Life Expectancy - Voltinism

Macroinvertebrates live in the water for anywhere from a few weeks to 100+ years! They are also typically unable to migrate only a short distance in their lifetime. Because of these facts, macroinvertebrates are good at integrating the effects of human activities on a stream over time. In the case of a temporary pulse of a pollutant, you may miss the window of time during which the pollutant was measurable in the stream if all you're measuring is the concentration of that pollutant. Certain components of the macroinvertebrate population, however, may be heavily depleted for months or years after such an event. Granted, they won't tell you exactly what pollutant was present, but a change in their population will at least tell you there is a problem that needs to be further investigated and prevented in the future.

Generally speaking, voltinism is the number of life cycles (generations) that a species may go through during a given year. Below are several types of voltinism that are used to describe the longevity of freshwater macroinvertebrates and examples of each.

- **multivoltine** - more than one generation each year; life expectancy from egg to post-reproducing adult is 1/2 of a year or less - *midges, blackflies, small minnow mayflies*
    - ***bivoltine*** - may also be used in describing life cycles with 2 generations/year
- **univoltine** - one generation each year; life expectancy from egg to post-reproducing adult is 1 year - *many mayflies, caddisflies, and stoneflies*
- **semivoltine** - more than one year for each generation; life expectancy from egg to post-reproducing adult is more than one year - *freshwater mussels, many dragonflies and stoneflies*

Metamorphosis

Macroinvertebrates become mature in a variety of ways. For example, the Crustacea and Mollusca tend to have a planktonic stage that floats around a while before settling. Once they

settle, they just get larger and larger either through molting (crustaceans) or by adding growth to their shell (mollusks).

Insects also have some variation in the way they grow from egg to adult, but it can be broken down into two major groups: complete metamorphosis and incomplete metamorphosis.

Complete metamorphosis involves 4 major stages (see image below). The egg hatches. Larvae are the primary feeding and growth stage and may go through a number of molts. Once the larva is mature, it forms a non-feeding pupal case in which it changes dramatically. The adult then emerges from the pupal case to reproduce. Insects that go through complete metamorphosis include flies (Diptera), beetles (Coleoptera), caddisflies (Trichoptera), and hellgrammites (Megaloptera).

Incomplete metamorphosis involves 3 major stages (see image below). The egg hatches. Larvae are the primary feeding and growth stage and may go through a number of molts. As the larva becomes more mature, the wing pads develop on top of the middle and usually hind thoracic segments. Once the larva is mature, it usually crawls from the water; splits its exoskeleton along the upper middle; then the adult crawls out of the old skin (called exuvia once the adult is out). Insects that go through incomplete metamorphosis include mayflies (Ephemeroptera - which have an extra winged stage called sub-imago before they can reproduce), stoneflies (Plecoptera), dragon and damselflies (Odonata), and true bugs (Hemiptera). The adult mayfly in the image below is the sub-imago stage and must molt one more time before it will be sexually mature.

Tolerance

Macroinvertebrates must live the majority, if not all, of their life under water. Some are very tolerant to a variety of environmental conditions, but most have adapted to living under a particular set of environmental conditions and are very sensitive to changes in their environment. As human activities in a watershed change the chemistry, temperature, and physical characteristics of streams, the macroinvertebrates sensitive to these changes may not be able to survive.

Changes in water temperature and the amount of fine sediment in a stream are common challenges for macroinvertebrates, particularly when riparian cover or soil stability is affected by the removal of native vegetation by development, timber harvest, or agriculture. Organic enrichment from hatcheries, livestock, and sewage can lower the oxygen levels in water, severely affecting most macroinvertebrates. Some macroinvertebrate are particularly sensitive to heavy metals in the water from mining, industry, and urban runoff. Other forms of pollution come from a variety of

different sources including toxic oils from dams and boats; fertilizers and herbicides from pest control, agriculture, forestry, golf courses, and urban yards; acid rain (more of a problem in the East); and many other types of industry from paper manufacturing to dentistry.