



Macroinvertebrate Background

What are macroinvertebrates?

Macroinvertebrates are animals that lack a backbone (“invertebrate”) and can be seen with the unaided eye (“macro”). They include insects such as immature and/or adult mayflies, stoneflies, caddisflies, true flies (e.g. mosquitoes), dragonflies and beetles, as well as other invertebrates such as snails, leeches, worms and mussels. Aquatic macroinvertebrates spend the majority of their lives in streams, lakes and other aquatic environments. They depend on healthy aquatic and upland ecosystems to survive.

Aquatic macroinvertebrates are animals, just like we are, and like us they need oxygen to breathe. Aquatic macroinvertebrates can acquire dissolved oxygen across the surface of their bodies, but many types such as mayflies, damselflies, and stoneflies have elaborate branched, tufted or leaflike gills that help them obtain dissolved oxygen from the water. Still others have breathing tubes or siphons that they stick up above the surface of the water to breathe (water scorpions, mosquito larvae), while some aquatic beetles capture bubbles of air at the water’s surface and dive down with their own portable “scuba tank”.

Aquatic macroinvertebrates are affected by multiple different physical and chemical factors in both the stream and the surrounding watershed. The structure and composition of the aquatic macroinvertebrate community tells an important story about the biological health of our rivers and streams.

What is biological assessment?

Biological assessment uses the characteristics of biotic (living) communities, such as fish, invertebrates, amphibians, or plants to provide data about the biological “health” of a body of water. It allows us to detect biological responses to the effects of pollution and disturbance.

Measuring water quality alone (temperature, pH, heavy metals, etc) doesn’t give a complete picture of stream health. It isn’t possible to test for every different contaminant that might be present in a stream or lake, but the invertebrates live in that water all of the time. They are constantly exposed to whatever chemicals, sediments, or changes in the temperature may be occurring, and may respond by dying out, migrating away, or reproducing in even higher numbers, depending on the type of invertebrate.

Aquatic macroinvertebrates are excellent “bioindicators” i.e. biological indicators of environmental health and ecological function. They are found everywhere, generally in large numbers, and are easy to collect; they are confined to the aquatic environment for most or all of their life cycle; they integrate the effects of many stressors (sediment, temperature, pollution etc) over their life span; different taxa have different known responses to specific stressors and they are a critical part of the stream food web. Changes in the presence, condition, diversity, community, composition and relative abundances of specific groups of macroinvertebrates can indicate pollution or disturbance occurring in a stream or its watershed.



Macroinvertebrates and the Aquatic Food Web

Macroinvertebrates are critically important in the aquatic food web. Some serve directly as food for predators such as fish, amphibians, birds, and other invertebrates; others help make more food or nutrients available in the aquatic system by breaking down leaves and plant material. Fish populations depend on healthy macroinvertebrate populations to survive. The availability of macroinvertebrates as food is determined by both the physical and biological condition of the stream.

Macroinvertebrates have a wide variety of shapes, sizes, appearances, and mouth parts, and this diversity reflects a diversity of feeding habits as well. Macroinvertebrates may feed on living material (algae, plants, or other invertebrates), as well as on dead or decomposing plants and animals and particles of organic detritus, and they are often classified according to the way in which they obtain their food. The major different functional feeding groups (FFG) are shredders, collectors, predators or shredders) but they are still a valuable method of classifying the stream macroinvertebrate community. By looking at the feeding habits of these invertebrates, you can begin to sort out different roles these animals play in the ecology of watersheds. The main categories of functional feeding groups include:

Shredders

Chew on intact or large pieces (>1 mm) of plant material
Usually found in headwaters and areas with a high percentage of canopy cover
Examples. giant stoneflies, Northern caddisflies
Found in leaf packs, water-logged wood, headwater streams

Scrapers/grazers

Scrape off and consume thin layer of algae growing on solid substrates in shallower waters
Examples: snails, flatheaded mayflies, water pennies
Found under rocks and more open areas with enough sunlight to support algal growth; rocks in open- canopied areas, mid-stream reaches

Collectors (collector/filterers and collector/gatherers)

Consume very small pieces of detritus (<1 mm)
Examples: common netspinner caddisflies, back flies, brush-legged mayflies, mussels
Found in rocks and mud; common in all reaches, but make up larger proportion in lower reaches where sediment collects

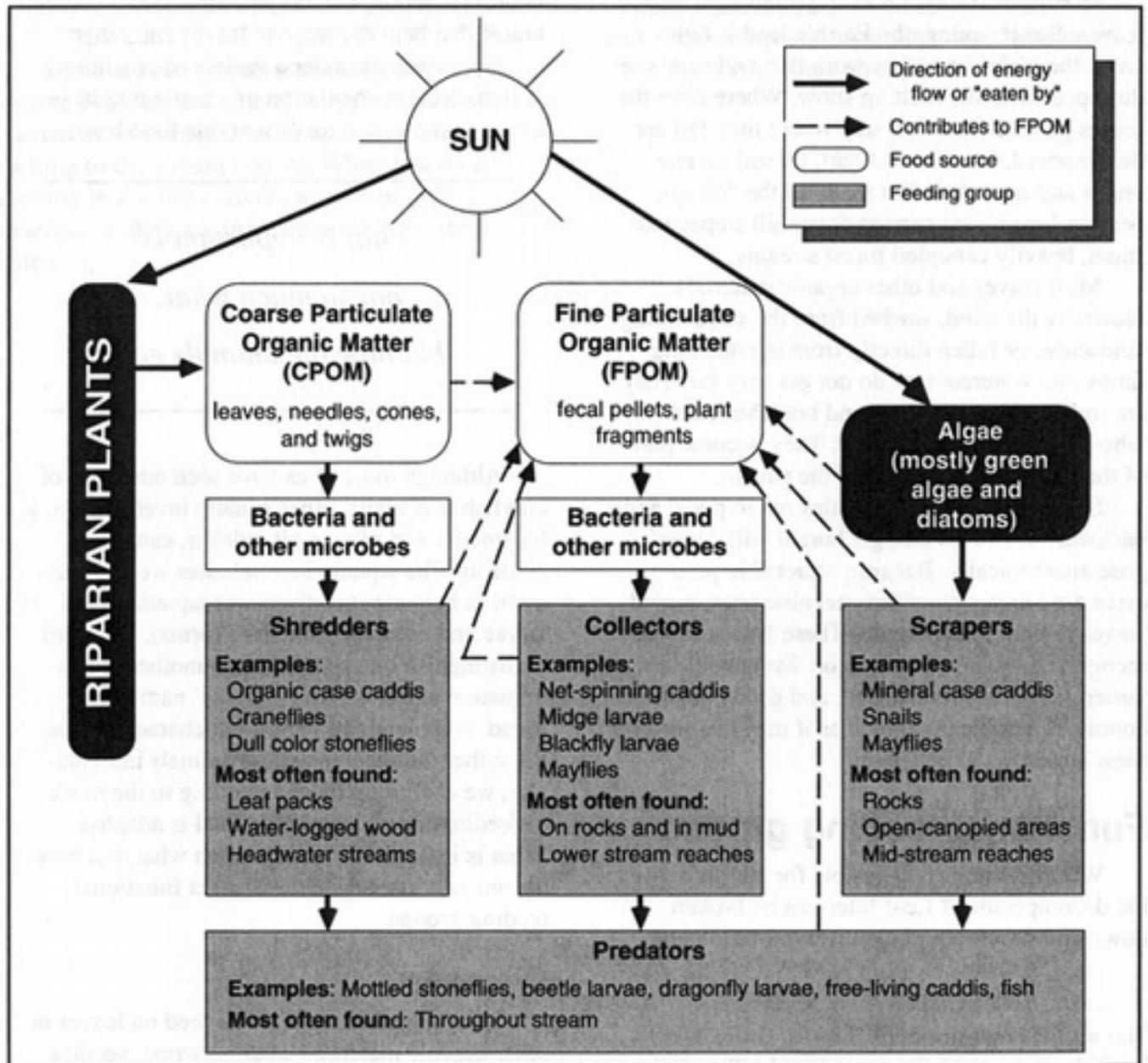
Predators

Feed on living animals; may swallow smaller prey whole, tear pieces out of larger prey, or suck out body fluids
Examples: predaceous diving beeiles, dragonfly larvae, common stoneflies
Found in: all habitat types, in smaller proportion relative to other feeding groups



Pathways of energy from the sun to the four main macroinvertebrate groups. Some scientists add salmon carcasses as another source of energy.

Food Processing in Streams



Adapted from: Ken Cummins, "From Headwater Streams to Rivers," *American Biology Teacher*, May 1977, p. 307.



The River Continuum

The river continuum concept (RCC) is a model that describes running water systems using elements such as stream width, depth, velocity, channel shape, and associated biological communities. Because stream morphology, vegetation, and energy inputs change from headwaters to mouth, biological communities in a stream also change in a somewhat predictable pattern. This pattern is influenced by channel structure, gradient, bank stability, sediment loads, riparian vegetation, light penetration, and temperature.

A stream is a continuum that transports progressively smaller food materials from the headwaters to the lower reaches. Each year, large amounts of organic material fall into the headwaters of forested streams. Only 20-35% of this material is flushed downstream; the remaining organic input is retained and used by stream organisms. It can be processed by bacteria and fungi, physically abraded, or consumed by insects. As it is processed, organic debris is broken into smaller pieces, which increases their surface area and subjects them to further degradation by microbial action.

In this way, small 1st- and 2nd-order streams send partially prepared food into larger, higher order streams. Processing continues as small debris moves downstream through the system. Because different invertebrate functional feeding groups process different-sized food particles, different FFG communities are expected in different stream reaches.

Forests at the headwaters (1st- to 3rd-order streams) have less influence as a stream gets larger by flow volume. With less input from the riparian habitat, the energy base relies more on algae that is produced as additional sunlight penetrates through the open canopy, and on processed material carried in from intermediate or midreach (3rd- to 5th-order) streams. As the kind of organic material changes, the proportion of shredders decreases and the proportion of collectors and scrapers increases.

The midreaches of a stream system have a greater diversity of species than is found either upstream or downstream. The reason is not completely understood, but may be due to the fact that midreach water temperatures can change more than those of headwaters or larger rivers. The variety of organic substrates and physical components found in midreach streams may also have an effect.

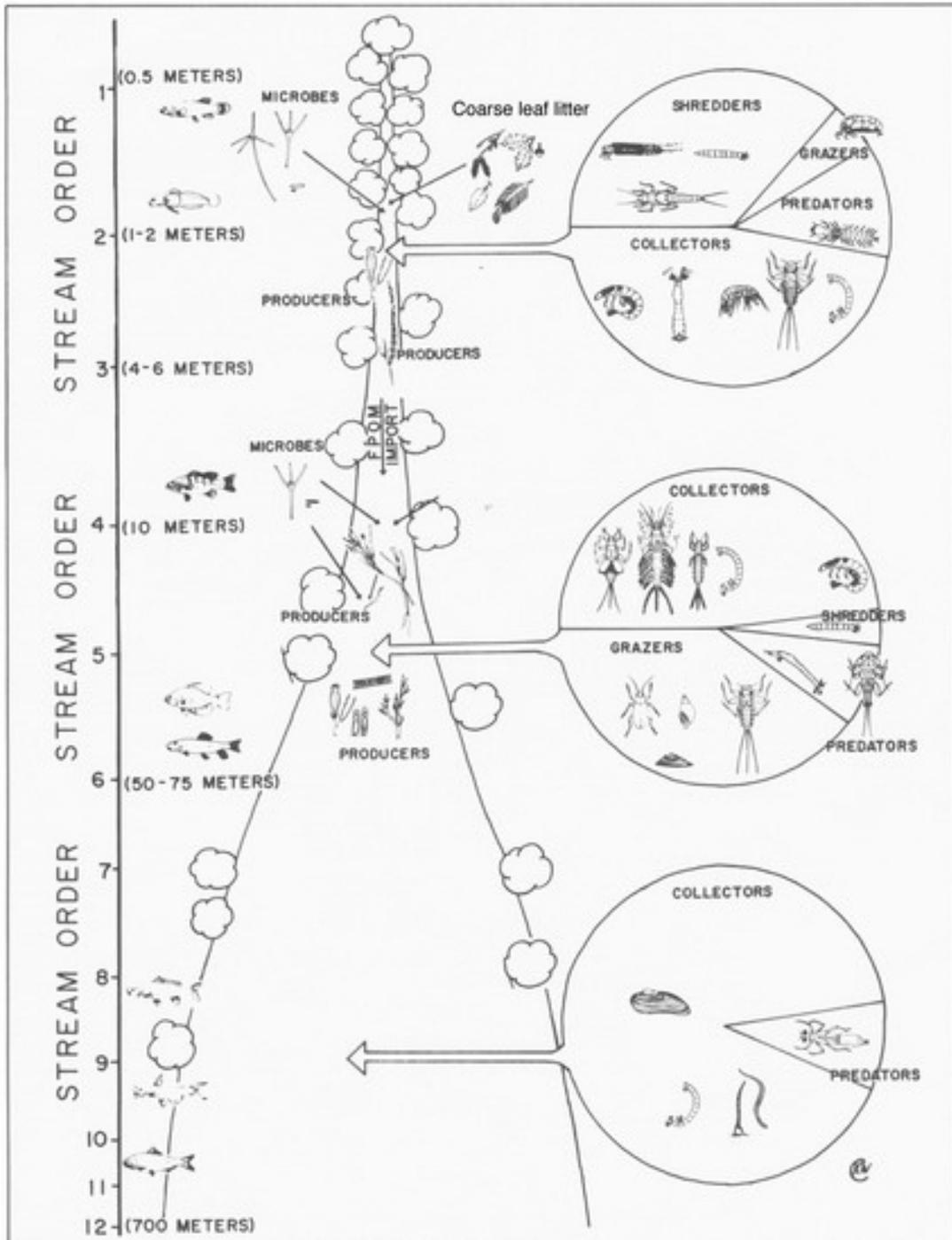
Turbidity increases in the lower reaches (6th- and higher-order streams) due to greater loads of fine sediments from tributaries and downstream movement of processed particulate matter. Collectors dominate these reaches, and the diversity of other organisms decreases. Increased turbidity reduces light penetration and thereby reduces the efficiency and photosynthetic production of algae in larger streams. Large plankton communities are important in these areas, RCC predictions. RCC work particularly well for forested mountain streams.

There are exceptions to the pattern outlined in The River Continuum, but the concept shows what might be expected in a stream system. If a macroinvertebrate community is "out of place" or missing, it can be a red flag, encouraging further investigation.



The River Continuum Concept (after Vannote et al., 1980).

Changes in functional feeding groups accompany changes in stream morphology and energy inputs.





In-Depth Sampling Strategies and Collecting Techniques

Macroinvertebrates can be found just about anywhere in streams-fast-flowing riffles, slower glides, and quiet pools, as well as in tangled rootwads overhanging the stream bank, matted leafpacks, and piles of large woody debris in the water. Riffles are shallower areas with medium to fast current where the flowing water breaks and churns over a mixed gravel, cobble and boulder substrate, and are the preferred sampling habitat because they:

- Contain the greatest diversity of macroinvertebrates.
- Are the most likely place to find pollution-sensitive species.
- Have fairly consistent habitat throughout the riffle.
- Are shallow and easy to access.
- Are easy to recognize.
- Contain cooler water and thus higher dissolved oxygen.

Riffle sampling is done using a D-frame dip net with 500 micron mesh, which is a small enough mesh to retain even tiny macroinvertebrates. Place the net base firmly against the stream bottom at the desired sampling location with the opening facing the current, and stand behind or to the side of the net to avoid obstructing the flow of water into the net bag. Make sure the water is not deeper than the top of the net (or you will lose organisms over the top), and that the base of the net is flush against the substrate (or you will lose organisms under the net bottom).

If the net base is resting on rocks, carefully move the rocks to the net opening and rub them gently to dislodge any clinging organisms, then set them aside. Once the net rim is flush against the substrate, pick up any large rocks or cobble present in a 1-foot square area in front of the net, and gently rub them clean while holding them at the net opening so that any dislodged organisms are carried into the net by the current. Set the cleaned rocks gently aside. Leaves may also be 'rinsed' into the net to dislodge any macroinvertebrates. Then use your boot heel or a small hand rake to thoroughly disturb the substrate in the same 1-foot square area in front of the net to a depth of about 2-3 inches for 30-60 seconds. When finished, carefully tilt the net handle slightly backwards to avoid losing your sample, lift the net out of the water and empty the contents into a large bucket or plastic tray for sorting and observation.

After allowing the sample to settle for a few minutes, macroinvertebrates can be picked out carefully from the debris using forceps (tweezers) and pipettes (eyedroppers or turkey basters). Most of these animals are dark colored and cryptic, blending in with the background, so they may be difficult to see at first, but look for movement once collected materials settle. Individual organisms can be transferred to the chambers of white ice cube trays filled with water for easier viewing. Remember that many of these animals are predators, and if you mix together different kinds of invertebrates in the same ice cube chamber they may start eating each other!



In-Depth Sampling Strategies and Collecting Techniques

Students can use the identification cards and field guides provided to help identify and record the numbers of each different general type (order or family, functional feeding groups, etc.) of invertebrate found. They can also use the pollution tolerance levels and sensitivity ratings in the guides to determine if they have found more invertebrates from the tolerant (midges, black flies, snails, aquatic worms) or intolerant groups (mayflies, stoneflies, caddisflies).

These tolerance levels are based in part on the Hilsenhof Biotic Index (HBI), a numeric value related to an organism's sensitivity or tolerance to nutrient enrichment (resulting from fertilizer runoff, manure, or sewage) in a stream or lake. Low values (0 to 4) indicate an organism is sensitive to nutrient enrichment, while high values (8-10) indicate intolerance.

Students can also calculate the overall community richness, i.e. the number of different groups present. Most students will be able to identify the number of different invertebrate orders present, and some may be able to identify different families and even a few genera. A healthier aquatic system should support a greater number of different organisms, including more pollution-sensitive types, while a degraded community becomes has lower overall richness, and is dominated by one or a few pollution-tolerant types.





MACROINVERTEBRATE SAMPLING & IDENTIFICATION

Objectives

Students will understand the importance and roles of macroinvertebrates in the aquatic ecosystem by:

- 1) Collecting macroinvertebrates from different instream microhabitats (if present)
- 2) Counting and recording invertebrates from each habitat (if present) (use the provided StreamWebs data form)
- 3) Analyzing the data to determine the health of the stream (in accordance with background materials)

Teaching Tips

- Get students focused with introductions.
- Review safety guidelines and site protocols:
 - Macroinvertebrate sampling should be conducted well away from and downstream from spawning salmon and redds.
 - No more than four students in the stream/river at a time.
 - Avoid fast-moving water.
 - Take care when walking on slippery rocks.
 - Never drink the water—it could make you sick
- Briefly describe the activity/model in-stream collecting techniques
- Divide students into teams for each activity: collecting, sorting, identifying, etc. Insects can be divided by order (broad categories mayfly, stonefly, caddisfly, other groups).
- Use field guides/cards to determine insect types
- Tolerant/intolerant to pollution sheets can be passed out for de-brief/wrap up

Materials

- D-frame nets or kicknets
- Large shallow pans for sorting
- Ice cube trays for specific sorting
- Hand lens or 2-Way Magnifying Viewer
- Forceps, brushes, turkey basters, eye droppers for picking up invertebrates
- Guide to Pacific Northwest Aquatic Invertebrates Second Edition
- Pollution tolerance group key
- Tolerant/Intolerant to Pollution Macro sheets
- Clipboard, data sheets, pencils
- Rubber knee boots
- StreamWebs Macroinvertebrate Sampling Data Form (provided with equipment)



MACROINVERTEBRATE SAMPLING & IDENTIFICATION

Procedure

1. Review safety procedures
2. Identify the microhabitat(s), ie: riffle, pool, to be sampled
3. Collect sample from 1-square foot area immediately upstream from the net opening. To do this, approach site from downstream. Hold net downstream from area to be sampled, perpendicular to flow. Upstream, begin rubbing rocks, stocks or other leaf litter to remove any invertebrates. The invertebrates should slow into the net. Replace the rocks.
4. Repeat in up to 3 other locations if necessary.
5. Remove net contents into a large shallow tray for sorting into groups in ice cube trays.

Tip: It can help to use the analogy of a zoo when discussing the reasoning for sorting. In the zoo all animals are not in the same cage. You wouldn't see a lion in the same cage as an elephant; therefore we do our best to put all the mayflies with the mayflies and caddis flies with the caddis flies.

6. Count the different kinds of invertebrates and numbers of each kind for reach of the four functional feeding groups. Use the field guides to help with identification.
7. Macros can also be sorted by habitat type or where found in the stream.
8. Record these numbers on the Streamwebs data sheet provided with the equipment.
9. Gently return macroinvertebrates to the stream.

For Discussion/wrap up

Determine the health of the stream by the number/variety of insects found. Use the tolerant/intolerant insect group sheets provided. Which group best reflects the insect community found in the stream sampled?

Habitat Requirements Questions

- What species are you more likely to find in moving water? Calmer water?
- Which particular nymph type (immature form) is only found in fast, cold water?
- Why might one insect need less dissolved oxygen than another?
- Why is there more dissolved oxygen in a fast flowing stream than in a pond?

Macroinvertebrates and Water Quality

- Why are macroinvertebrates good indicators of water quality?
- What area of the stream contains the most diverse assemblage of insects?
- What species would be more likely found in stagnant areas with more fine sediments?
- What kinds of links on the food chain are filled by aquatic insects? (herbivores, carnivores, detritivores (insects that eat dead stuff))

What can you do?

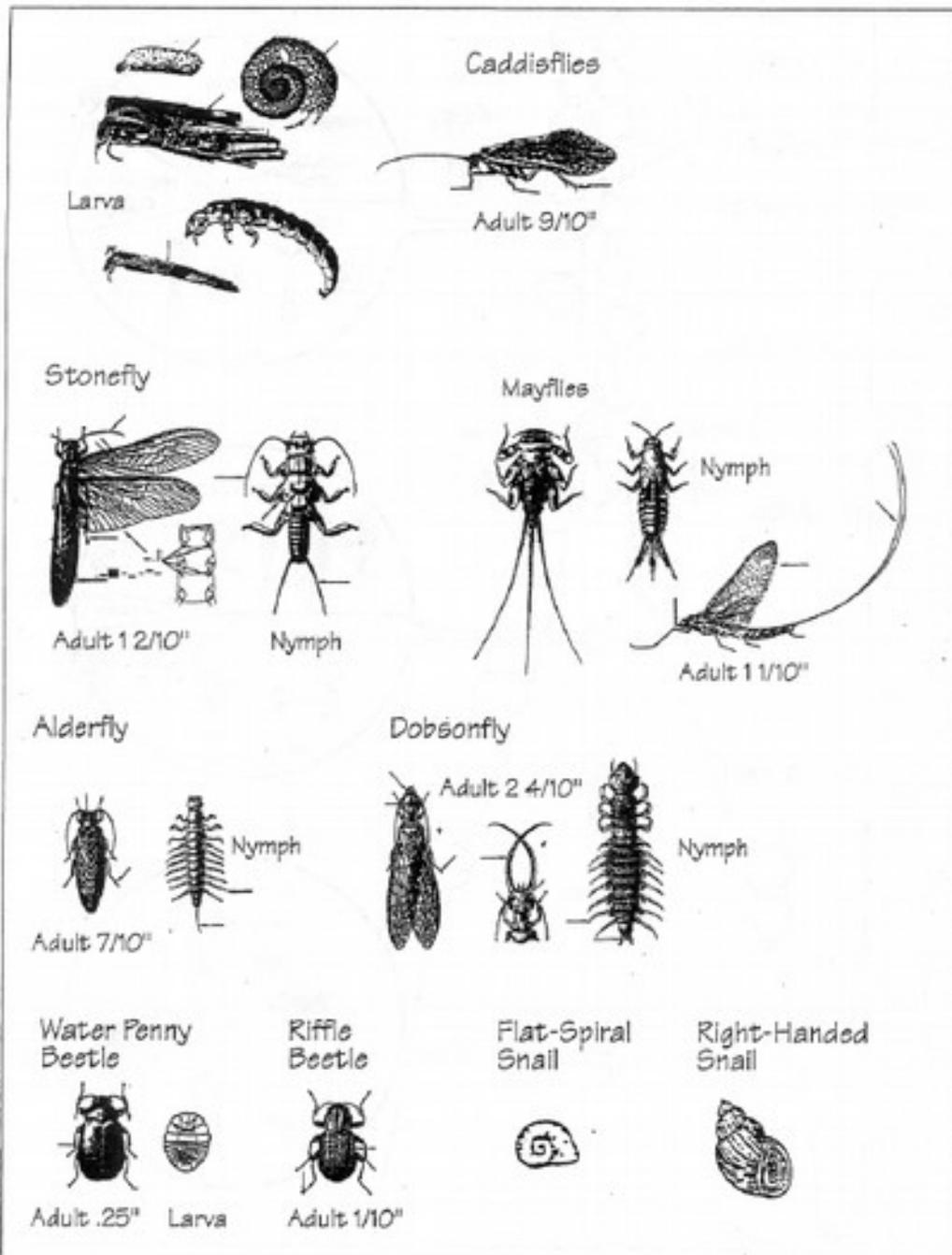
- What measures can be taken to protect a stream with healthy macroinvertebrate populations that support salmonids?
- What measures can be taken to help restore a system that has been degraded and has lost the diversity of insects that are part of a healthy watershed for fish?



INSECT GROUPS ARRANGED BY TOLERANCE TO POLLUTION

Group 1: Intolerant

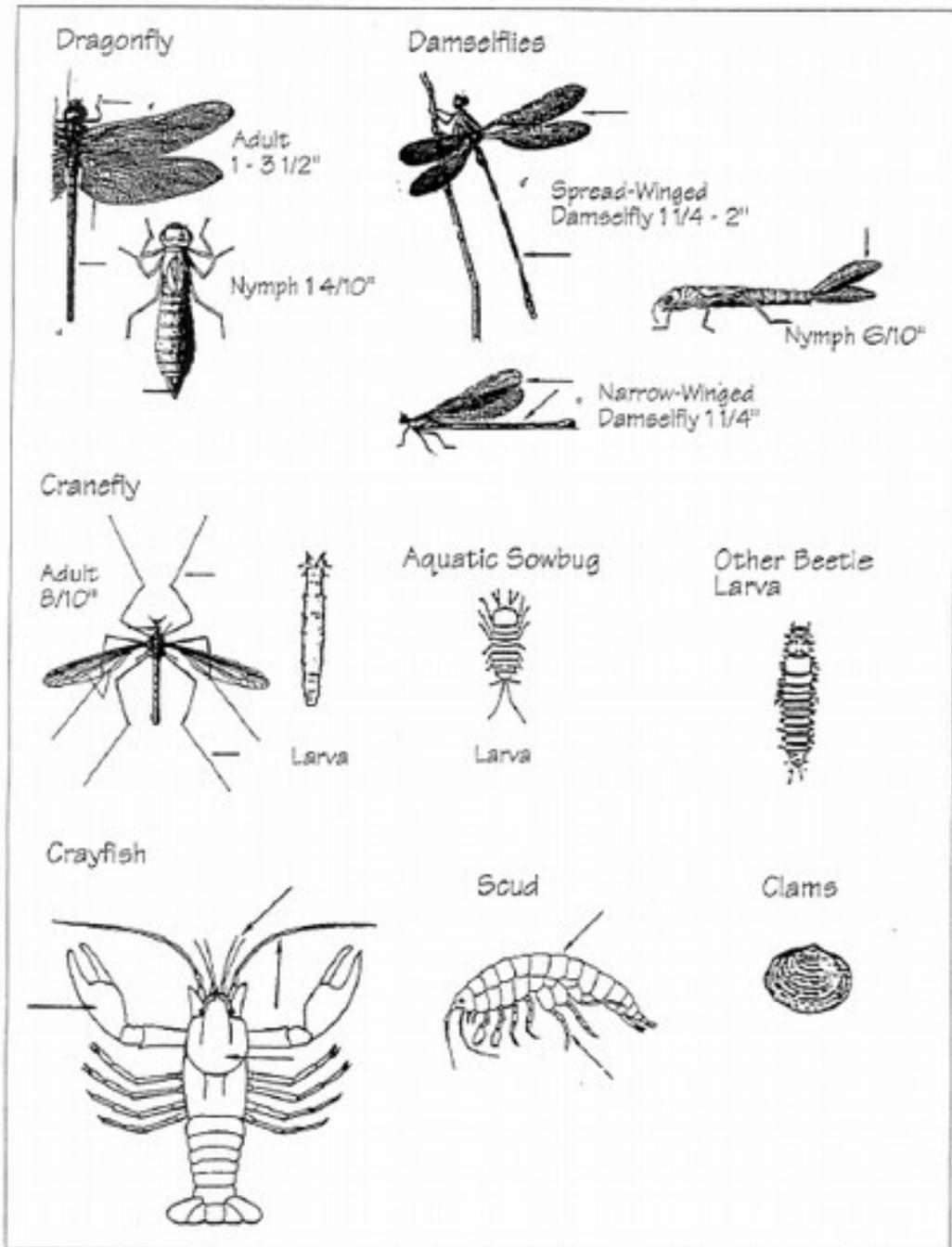
These organisms are sensitive to pollution.
Their dominance generally suggests good water quality.





Group 2: Somewhat Tolerant

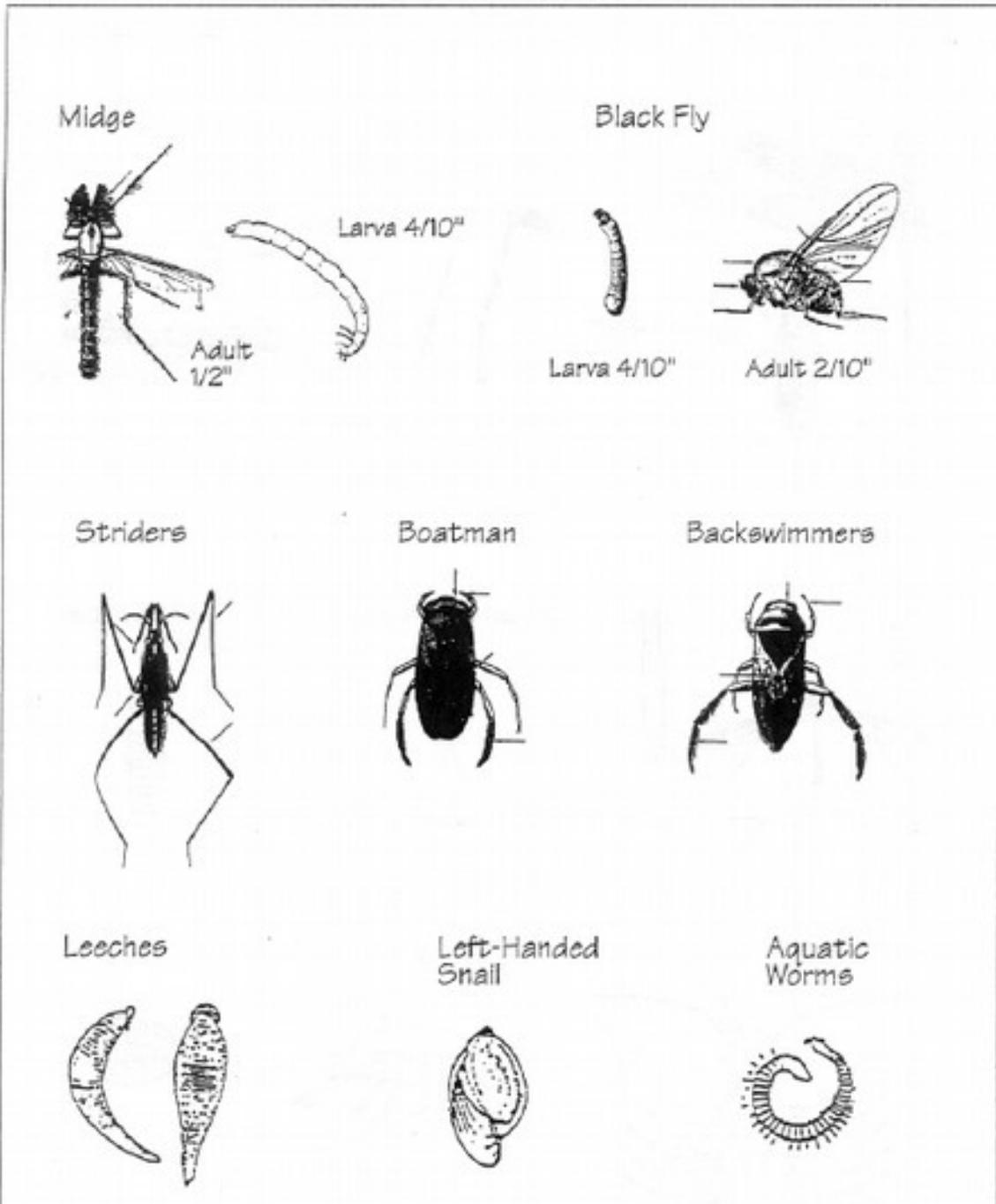
These organisms can tolerate a wider range of water quality conditions.





Group 3: Tolerant

These organisms are generally tolerant of pollution. Their dominance suggests poor water quality.





QUICK REFERENCE GUIDE TO AQUATIC INVERTEBRATES

| Name | Distinguishing Characteristics | Where Found | How Oxygen is Obtained | Food Gathering | Things To Look For |
|--|--|--------------------------------------|--|------------------------------------|---|
| Stonefly Nymph  | 2 tails, 2 sets wing pads, (wing pads not always noticeable) | Cold running water | Through body surface; some small gills; does "pushups" to increase oxygen flow | Predator or herbivore | Streamlined body for crawling on rocks; requires high oxygen levels |
| Mayfly Nymph  | 3 tails (sometimes 2); 1 set wing pads. | Cool or cold running water | Through gills along abdomen; may wave gills in water to increase oxygen flow | Herbivore or scavenger | Requires high to medium oxygen levels |
| Caddisfly Larva  | Most species build cases or nets soft body, some free living | Cool or cold running water; ponds | Through body surface; some finger-like gills | Filter feeder, herbivore, predator | Builds cases of heavy material (rocks) to avoid being swept away by fast-flowing streams; uses grass and plants to make cases as well |
| Water Penny Larva  | Round, flat, segmented, disk-like body | Cold running water | Usually through gills on underside | Herbivore—grazes on algae | Flattened body resists pull of current |
| Predaceous Diving Beetle Larva  | Up to 6 cm long; robust jaws | Most still and moving water habitats | Through body surface | Voracious predator | Special channels in jaws to suck body fluids of prey |



| Name | Distinguishing Characteristics | Where Found | How Oxygen is Obtained | Food Gathering | Things To Look For |
|---|---|---|---|-----------------------|--|
| Whirligig Beetle  | Black; congregates in schools | Surface of quiet water | From atmosphere | Predator or scavenger | Has two pairs of eyes to see above and below water's surface; has type of "radar" to locate object in water; secretes white odorous substance to deter predators |
| Black Fly Larva  | Small body; small hooks at end of abdomen attach to rocks | Cold running water | Through body surface; small gills | Filter feeder | Anchors to rocks with silk; only needs medium to high oxygen levels |
| Dragonfly Nymph  | Stout body; arm-like grabbing mouthpart | Cool still water | Dissolved oxygen, through gills in internal body chamber | Active predator | Clings to vegetation or hides in clumps of dead leaves or sediment |
| Damselfly Nymph  | 3 leaf-like gills at end; arm-like grabbing mouthpart | Cool still water | Through gills at end of abdomen | Active predator | Clings to vegetation or hides in clumps of dead leaves or sediment |
| Hellgrammite (Dobsonfly, Alderfly or fishfly Larva)  | Up to 9 cm. Long | Cool or cold, slow to fast moving water | Through gills along side of abdomen; some fish flies have breathing tubes | Active predator | Can swallow prey without chewing |



| Name | Distinguishing Characteristics | Where Found | How Oxygen is Obtained | Food Gathering | Things to Look For |
|---|---|--|--|---|--|
| Water Strider Adult  | Skates on water's surface | Ponds or still pools of stream | From atmosphere | Active predator | Can stay on water's surface because feet have small surface area and are water repellent |
| Water Boatman Adult  | Long swimming hairs on legs | Ponds or still pools of stream | From atmosphere, by carrying air bubble from water's surface on body | Omnivore, herbivore, or scavenger | Has swimming hairs on legs that act as oars |
| Backswimmer Adult  | Light-colored underside; swims on back | Ponds or still pools of streams | From atmosphere, by carrying air bubble from water's surface on body | Predator | Swim on back, sleek body shape |
| Crane fly Larva  | Cylindrical body; often has lobes at hind end, may have small soft legs | Bottoms of streams and ponds in sediment and algae | From atmosphere through spiracles (openings) at hind end | Active predator, herbivore, or omnivore | Species that eat woody decaying matter have gut bacteria to digest cellulose |
| Mosquito Larva  | Small body; floats at surface | Cool to warm still water | From atmosphere through breathing tube, on hind end as a larva and front end as pupa | Scavenger — feeds on micro-organisms | Swims or dives when disturbed |



| Name | Distinguishing Characteristics | Where Found | How Oxygen is Obtained | Food Gathering | Things to Look For |
|---|--|---|--|--|--|
| Aquatic Sowbug  | Flattened body, top to bottom; 7 pairs legs | Shallow freshwater, among rocks and dead leaves | Through body surface on legs | Scavenger —eats decaying matter— or omnivore | Male clasps female under it during mating; female then sheds half of exoskeleton, which becomes case into which fertilized eggs are placed |
| Crayfish  | 5 pairs of legs, first pair often robust; looks like small lobster | Under rocks or in burrows in shallow freshwater | Through gills under body | Scavenger or omnivore | Crawls backwards when disturbed; males display some courtship behavior to reduce female aggressiveness |
| Scud  | Flattened body, side to side swims on side | Bottom of lakes, streams or ponds, or streams | Through gills under body | Scavenger or omnivore | Male carries female on its back during mating; female then sheds half of exoskeleton, which becomes case into which fertilized eggs are placed |
| Midge Larva  | Small thin body with a hard head and small legs on the hind end | Most still and moving water habitats | Through body surface, small gills | Predator, herbivore, or omnivore | Extremely common; sometimes red because they have hemoglobin in their blood to help transport oxygen; wiggle actively |
| Rat-Tailed Maggot Larva  | Cylindrical body; tail-like breathing tube | Cool to warm water with low oxygen levels | From atmosphere through breathing tube | Scavenger —eats decaying matter and sewage | Can survive low oxygen levels fatal to most invertebrates |



Resource List

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