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 mayflies, mosquitoes, and beetles, as well as mussels, leeches, sideswimmers, and worms. Aquatic macroinvertebrates spend the majority, if not all of their lives in streams, wetlands, 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 leaf like 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 water 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": 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 signal 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 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 material and particles of organic detritus, and they are often classified according to the way in which they obtain nutrients. The major different functional feeding groups (FFG) are shredders, collectors, scraper/grazers, and predators. These distinctions are somewhat artificial, as some may fit into more than one category (i.e. scrapers may eat detritus while they graze on algae), 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.
Examples: giant stoneflies, Northern caddisflies
Found in: leaf packs, water-logged wood, headwater streams and areas with a high percentage of canopy cover

Scrapers/grazers

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

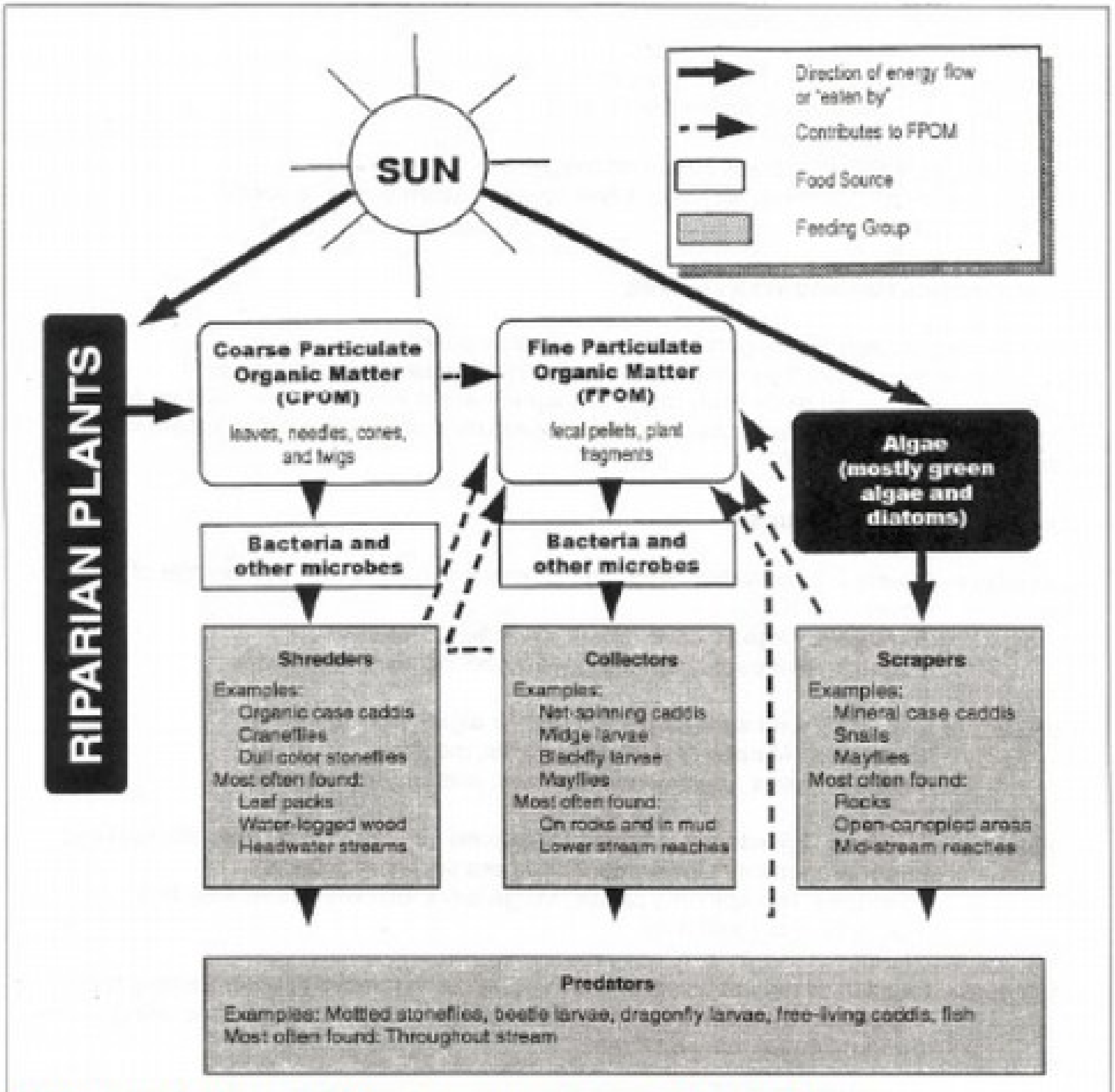
Collectors (collector/filterers and collector/gatherers)

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 beetles, 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. (*Adopted from "From Headwater Streams to Rivers," by Ken Cummins, 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. 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.

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

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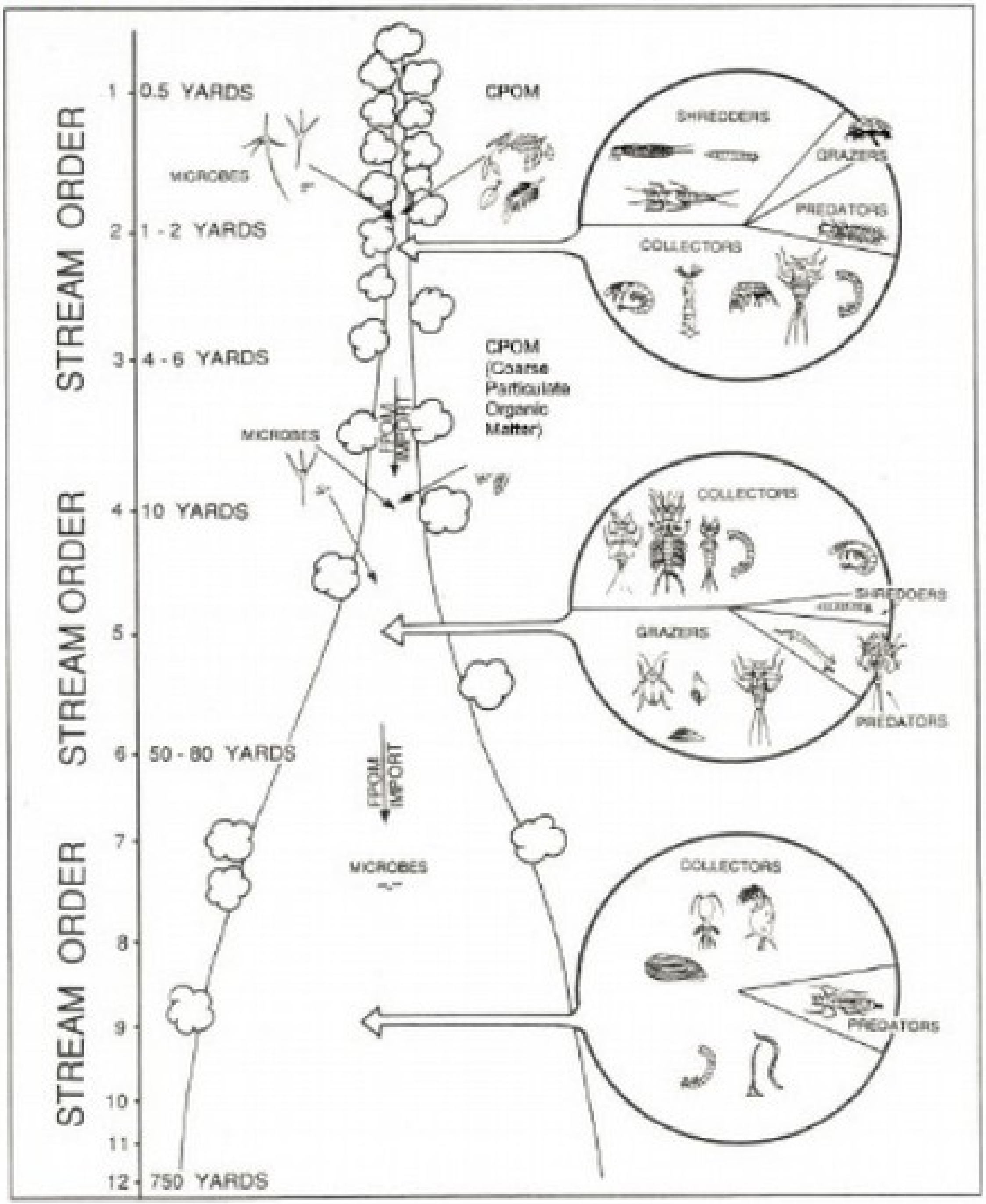
The River Continuum Concept

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

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. One 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. 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 nest 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. 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) 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 lndex (HBl), 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.

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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)

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MACROINVERTEBRATE SAMPLING & IDENTIFICATION

Procedure

1. Review safety procedures
2. Identify the microhabitat (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?

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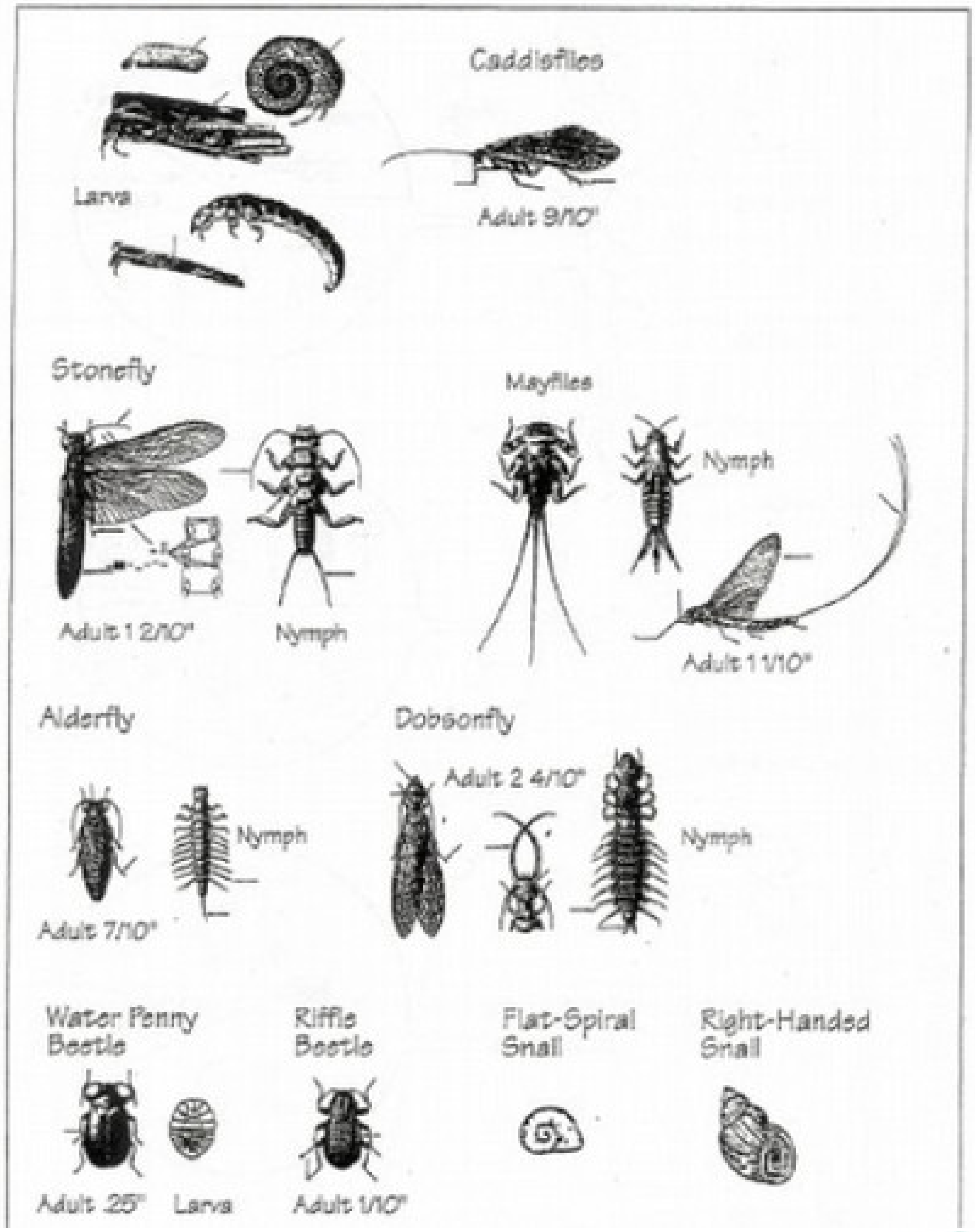
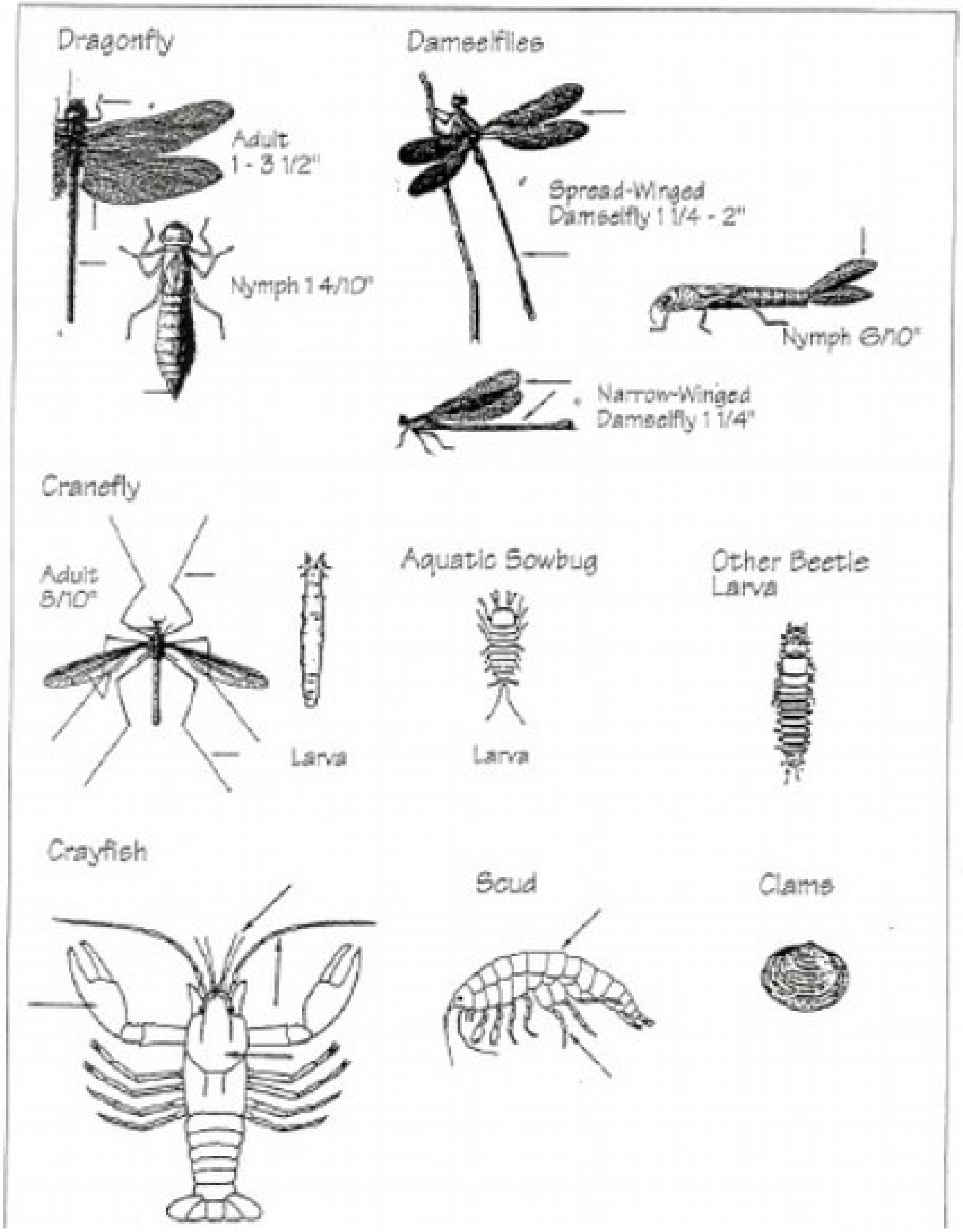
INSECT GROUPS ARRANGED BY TOLERANCE TO POLLUTION

Group 1: Intolerant
These organisms are sensitive to pollution.
Their dominance generally suggests good water quality.



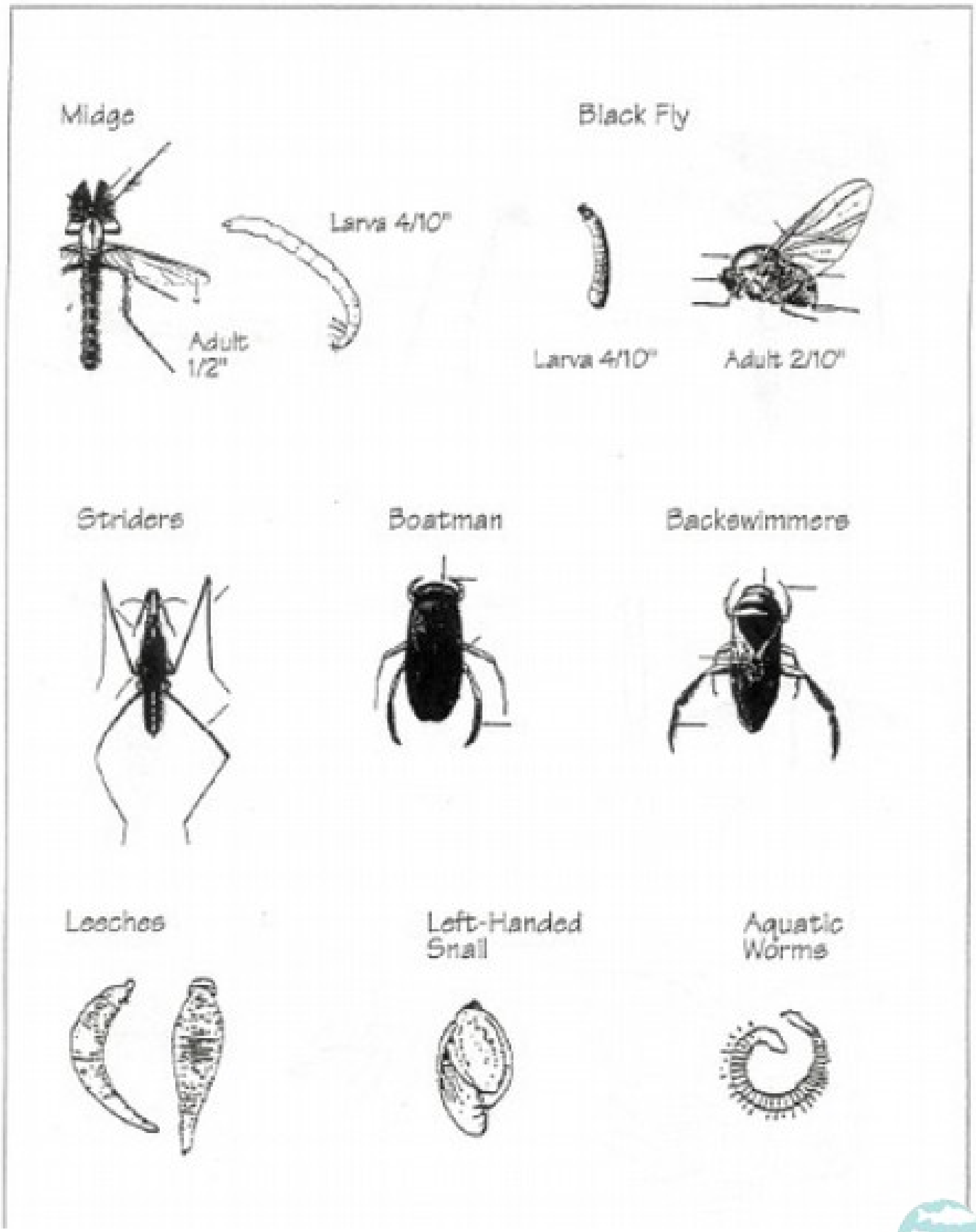
Group 2: Somewhat Tolerant

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



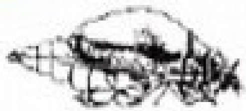
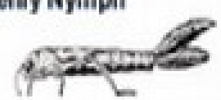
Group 3: Tolerant

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

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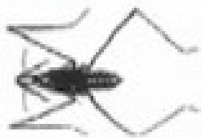
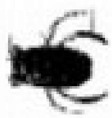
Name	Distinguishing Characteristics	Where Found	How Oxygen is Obtained	Food Gathering	Things to Look For
Water Strider Adult 	Skates on water's surface	Ponds or still pools of stream	From atmosphere	Active predator	Can stay on water's surface because feet have small surface area and are water repellant
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
Cranefly 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

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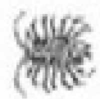
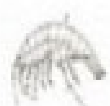
Name	Distinguishing Characteristics	Where Found	How Oxygen is Obtained	Food Gathering	Things to Look For
Aquatic Sowbug 	Flattened body, top to bottom; 7 pairs legs	Shallow freshwater, among rocks and dead leaves	Through body surface on legs	Scavenger —eats decaying matter—or omnivore	Male clasps female 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

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Resource List

Adams, J., M. Vaughan, and S. Black. 2004. Stream Bugs as Biomonitors: A Guide to Pacific Northwest Macroinvertebrate Monitoring and Identification. The Xerces Society for Invertebrate Conservation, Portland OR.

The Cascade Streamwatch Experience, Wolftree, Inc. March, 1996.

Farthing, P., B. Hastie, S. Weston, and D. Wolf. 1990. The Stream Scene, Watershed, Wildlife, and People, Oregon Department of Fish and Wildlife.

Hafele, R. and S. Hinton. 2003. Guide to Pacific Northwest Aquatic Invertebrates, 2nd ed.

Kellog, L. 1992. Monitor's Guide to Aquatic Macroinvertebrates, Izaak Walton League of America.

Lehmkuhl, D. M. 1979. How to Know the Aquatic Insects. William C. Brown Publishing Company.

McCafferty, W. P. 1988. Aquatic entomology: the fishermen's and ecologists' illustrated guide to insects and their relatives. Jones and Bartlett Publishers, Sudbury MA. 448 pp.

Mitchell, M. K. and W.B. Stapp. 1994. Field Manual for Water Quality Monitoring, 8th ed. Thomson-Shore, Inc., Dexter, Michigan.

Murdoch, T., M. Cheo and K. O'Laughlin. 2001. Streamkeeper's field guide: watershed inventory and stream monitoring methods. Adopt-A-Stream Foundation, Everett WA. 296 pp.

Nedeau, E. J., A. K. Smith, J. Stone and S. Jepsen. 2009. Freshwater mussels of the Pacific Northwest, 2nd ed. The Xerces Society for Invertebrate Conservation, Portland OR. 51 pp.

Voshell, J. R. 2002. A guide to common freshwater invertebrates of North America. McDonald & Woodward Publishing Company, Blacksburg, VA. 442 pp.

Wiedemer, S. and S. Chan. 2008. On the lookout for aquatic invaders: Identification guide for the Pacific Northwest. Oregon Sea Grant, Oregon State University, Corvallis OR. 71 pp.

Yates, S. A. 1988. Adopting a Stream, University of Washington Press, Seattle.