



Benthic Macroinvertebrates

Hidden beneath the surface of every healthy stream, a community of small invertebrates is doing the work of the ecosystem — shredding leaves, grazing algae, filtering particles, and becoming food for fish. These organisms are also **nature’s most reliable water quality report card**.

1. What are benthic macroinvertebrates?

Benthic macroinvertebrates are bottom-dwelling (benthic) animals without backbones (invertebrates) that are large enough to see without a microscope (macro). They include the aquatic larval or nymphal stages of insects such as mayflies, stoneflies, caddisflies, and dragonflies, as well as non-insect groups like crayfish, freshwater mussels, snails, worms, and leeches.

They live in all types of freshwater habitats — attached to rocks, burrowed in sediment, clinging to aquatic vegetation, or living under logs and leaf packs. Most spend the majority of their lives in the water before emerging as adults. They are found across all stream orders, from cold headwater riffles to warm lowland rivers.

Why are they such good bioindicators?

Reason	What it means in practice
Limited mobility	They can’t swim away from a pollution event — so their community reflects long-term conditions, not just a single snapshot.
Long life spans	Many species live 1–3 years as aquatic larvae, integrating water quality over months rather than a moment in time.
Wide diversity	Hundreds of species with very different pollution tolerances allow fine-grained assessments of water quality.
Pollution response is predictable	Sensitive species disappear first; tolerant species increase. This pattern is consistent and well-documented across Canada.
Easy to collect	Standardized kick-net sampling is low-tech, low-cost, and can be done by trained volunteers and students.
Key food web link	They convert leaf litter and algae into biomass that feeds fish — so their health reflects overall ecosystem function.
Detect habitat loss too	Unlike chemical tests, a biological survey can detect impacts from sedimentation, flow alteration, or riparian clearing that don’t show up in chemistry.

2. Pollution tolerance groups

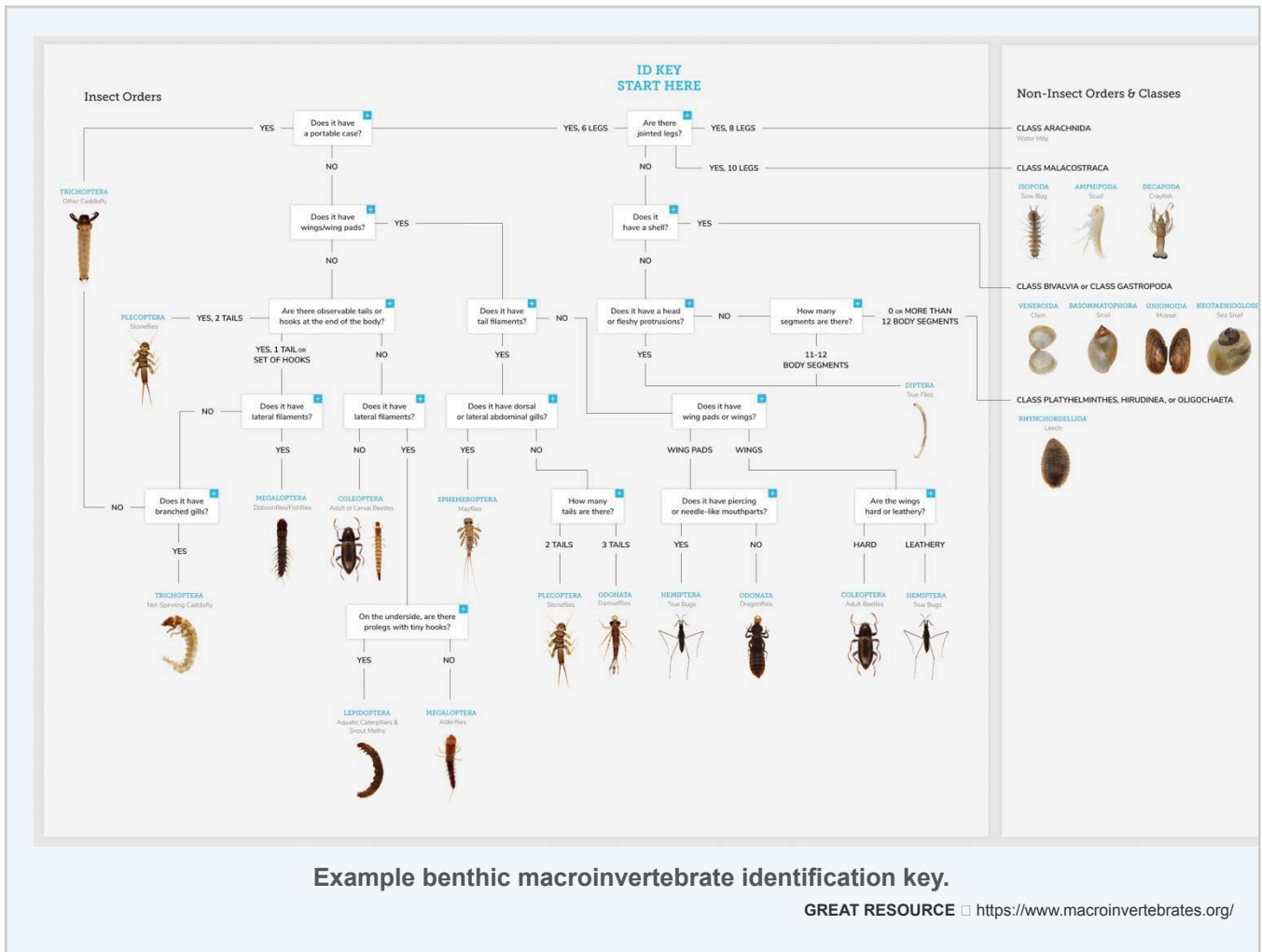
The key principle of macroinvertebrate bioassessment is that different species have very different tolerances for pollution. By looking at which groups are present and which are absent, we can infer the quality of the water over recent months.

The three-group system used in most Canadian and Envirothon programs broadly categorizes organisms from sensitive to tolerant:

Group 1 — Sensitive Indicate good water quality	Group 2 — Somewhat tolerant Fair to good water quality	Group 3 — Tolerant Present in any water quality
Stonefly (Plecoptera) <i>Needs high DO, cool clean water</i>	Crayfish <i>Omnivore; tolerates moderate stress</i>	Midge (Chironomidae) <i>Most abundant in impaired streams</i>
Mayfly (Ephemeroptera) <i>Most families sensitive to pollution</i>	Dragonfly (Odonata) <i>Active predator; moderately tolerant</i>	Blackfly (Simuliidae) <i>Filter feeder; tolerates high nutrients</i>
Caddisfly (Trichoptera) <i>Many species build cases from debris</i>	Damselfly (Odonata) <i>Slender larvae; near-shore habitats</i>	Aquatic worm (Tubificidae) <i>Thrives in low oxygen, high organics</i>
Water penny <i>Flat larva, attaches to rocks in riffles</i>	Beetle larvae (Coleoptera) <i>Variable tolerance by species</i>	Leech (Hirudinea) <i>Predator/parasite; very tolerant</i>
Riffle beetle <i>Lives in fast, well-oxygenated water</i>	Crane fly (Tipulidae) <i>Shredder; found in leaf packs</i>	Lung snail (Pulmonata) <i>Breathes air; survives low DO</i>
Dobsonfly <i>Large predatory larva; needs clean water</i>	Scud (Amphipoda) <i>Small crustacean; in leaf litter</i>	Pouch snail <i>Tolerates warm, slow, nutrient-rich water</i>
Gilled snail <i>Has gill, not lung; pollution-sensitive</i>	Sowbug (Isopoda) <i>Flat crustacean; collector-gatherer</i>	Rat-tailed maggot <i>Uses snorkel to breathe in polluted mud</i>
Planarian (flatworm) <i>Free-living; needs cool, clean water</i>	Clam / fingernail clam <i>Small bivalve; burrows in sediment</i>	Water boatman <i>Tolerates wide range of conditions</i>
Freshwater mussel <i>Filter feeder; sensitive to silt & low DO</i>	Fishfly / alderfly <i>Predatory; riparian-dependent adults</i>	

THE SCORING PRINCIPLE

A healthy stream will have organisms from all three groups, dominated by Group 1. An impaired stream will have few or no Group 1 organisms and be dominated by Group 3. When a site has only Group 3 organisms, water quality is almost certainly poor. When Groups 1 and 2 are abundant and diverse, the stream is in good ecological condition.



Macroinvertebrate Groups

by pollution tolerance

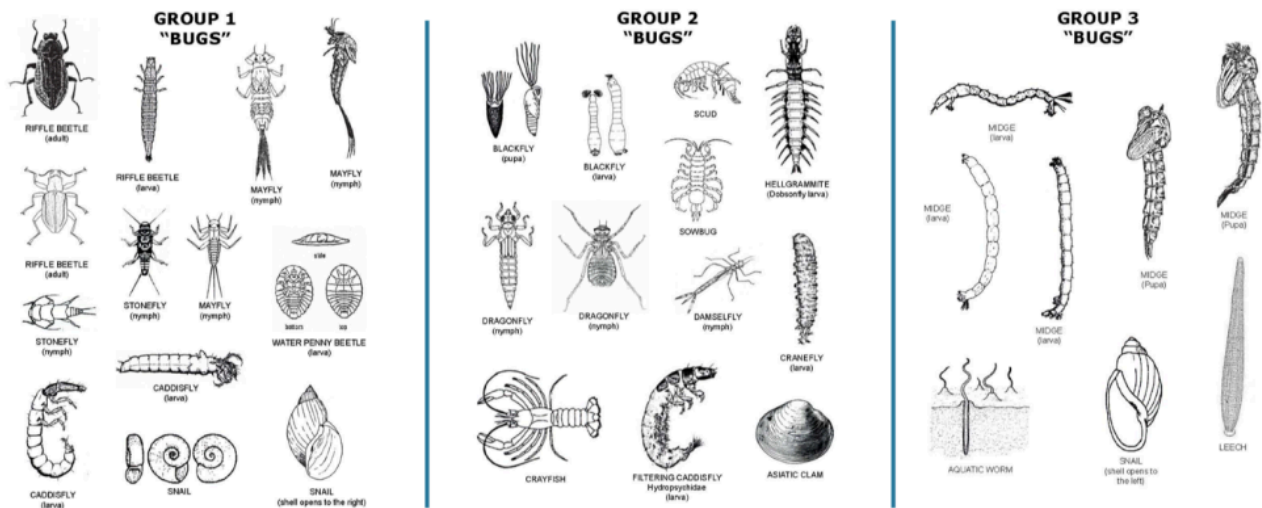


Photo credit: Alabama Water Watch

3. The EPT orders in detail

Ephemeroptera, Plecoptera, and Trichoptera — the EPT orders — are the cornerstone of macroinvertebrate bioassessment. High EPT richness (number of different EPT species) and high EPT abundance (% of total individuals that are EPT) both indicate good water quality. Understanding these three groups is essential for Envirothon.

Ephemeroptera — mayflies

Mayflies are among the most diverse aquatic insect orders — over 700 species in North America. Most are sensitive to pollution, making them key indicators. Nymphs are primarily scrapers and collectors, grazing algae from rock surfaces or gathering fine organic matter from the current. They are a critical food source for trout and salmon.

Key ID features: three tails (two cerci + one central filament), visible wing pads, gills along the abdomen. Life cycle: egg → nymph (aquatic, 1–3 years) → subimago (unique to mayflies) → adult (lives only hours to days). Adults do not eat.

CABIN metric: The % Ephemeroptera metric decreases in response to disturbance. Within the order, Baetidae (small swimmer mayflies) are more tolerant than most other families — a high proportion of Baetidae within the Ephemeroptera is itself a warning sign.

Plecoptera — stoneflies

Stoneflies are the most pollution-sensitive of the EPT orders. Most families require cold, fast, highly oxygenated water and are among the first to disappear when water quality degrades. Nymphs are either shredders (feeding on leaf litter in headwater streams) or predators (in larger streams).

Key ID features: two tails (cerci only), wing pads, often flattened body, two tarsal claws. Found primarily in riffles, clinging to rock undersides. Life cycle: egg → nymph (aquatic, 1–3 years) → adult (lives a few weeks).

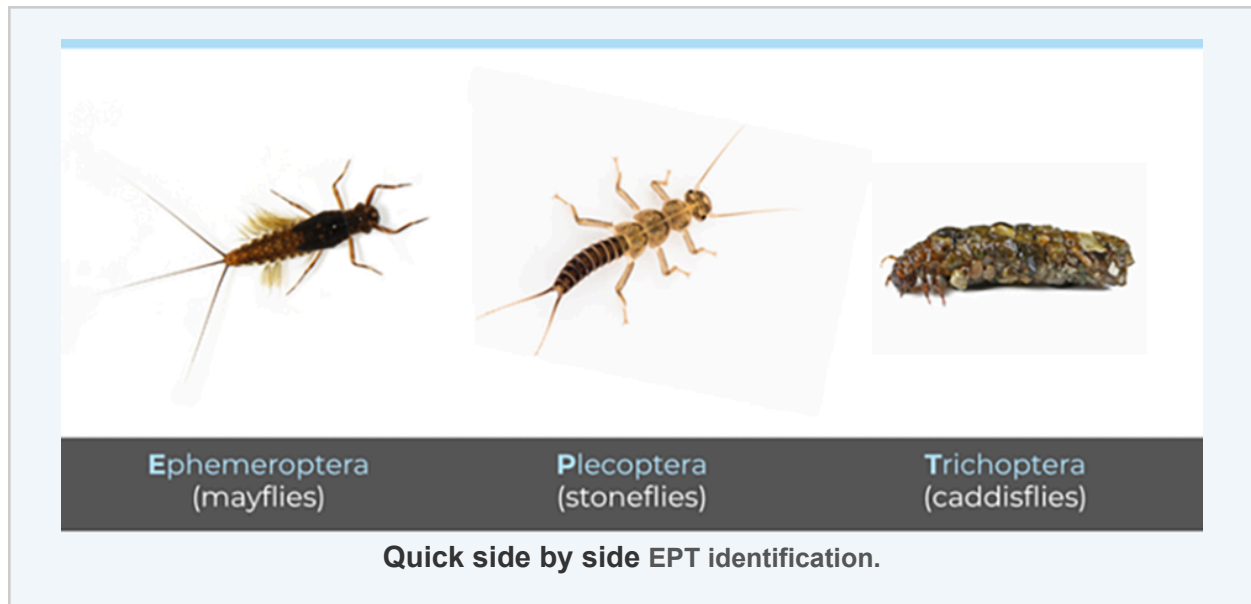
CABIN metric: Plecoptera richness is one of the most sensitive metrics to habitat degradation. Complete absence of stoneflies at a site that should support them is a strong signal of impairment.

Trichoptera — caddisflies

Caddisflies are remarkable for their larval cases — portable shelters built from sand grains, pebbles, leaf pieces, or twigs, cemented with silk. Case shape and materials are species-specific and can help with identification. Cases also protect larvae from predators and maintain position in currents. Not all caddisflies build cases — some are free-living net-spinners.

Key ID features: usually visible silk case; hook-like appendages at rear of abdomen; three pairs of true legs near head. Found in riffles, leaf packs, and on rock surfaces. Life cycle: egg → larva (aquatic, 1 year) → pupa (aquatic) → adult (moth-like; weeks).

CABIN metric: Within Trichoptera, Hydropsychidae (net-spinners) are more tolerant than most other families. A high proportion of Hydropsychidae within the caddisflies is a warning sign — similar to Baetidae within mayflies.



4. Functional feeding groups

Beyond pollution tolerance, macroinvertebrates are also classified by what they eat — their functional feeding group. This connects directly to the River Continuum Concept from Module 2: the proportion of each feeding group changes predictably from headwaters to large rivers, reflecting the energy sources available at each stream order.

PRO TIP: *it would be good to know the names of these functional feeding groups.*

Feeding group	What they eat	Where dominant	Examples
Shredders	Coarse particulate organic matter — leaves, twigs, wood (CPOM)	Orders 1–3 (headwaters) where riparian leaf input is high	Stonefly nymphs, crane fly larvae, some caddisflies
Collectors — gatherers	Fine particulate organic matter (FPOM) deposited on stream bottom	All stream orders; dominant in large rivers	Many mayflies, some midges, worms
Collectors — filterers	FPOM suspended in the water column; spin silk nets to capture it	Medium to large streams with steady flow	Net-spinning caddisflies (Hydropsychidae), blackflies
Scrapers / grazers	Periphyton (algae and biofilm) growing on hard surfaces	Orders 4–6 where sunlight reaches stream bottom	Water pennies, riffle beetles, some mayflies (Heptageniidae)
Predators	Other macroinvertebrates, tadpoles, small fish	All stream orders	Stoneflies (Perlidae), dobsonflies, dragonfly nymphs, water beetles
Shredders / piercer-herbivores	Living plant tissue (rare); pierce aquatic plants to feed	Aquatic macrophyte beds	Some moth larvae, water boatmen (partly)

FUNCTIONAL FEEDING GROUPS & THE RIVER CONTINUUM

Headwater streams (orders 1–3): shredders dominate, processing fallen leaves from the riparian canopy. Medium streams (4–6): scrapers and collector-filterers increase as sunlight drives algal growth. Large rivers (7+): collector-gatherers and filterers dominate, processing FPOM transported from upstream. A mismatch — e.g. few shredders in a headwater stream — suggests the riparian zone has been damaged and leaf input reduced.

5. Field collection — the CABIN kick-net method

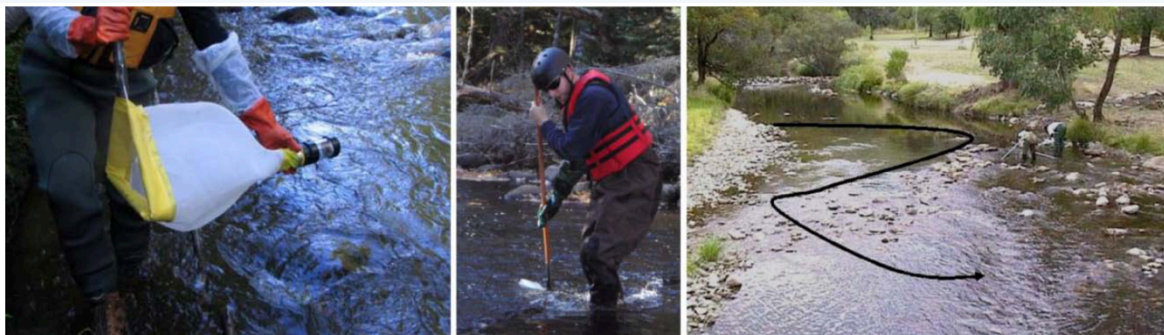
Standardized collection is critical — only comparable data is useful data. The CABIN protocol for wadeable streams uses a D-frame kick-net (500 µm mesh) and collects from riffle habitat, which is where EPT taxa are most abundant and results are most comparable between sites.

Step-by-step field procedure

Step	Action
1	Select a riffle section — fast-flowing, with cobble or gravel substrate. Avoid pools and backwaters.
2	Measure and mark a 1-metre-wide sampling area. Work from downstream to upstream.
3	Place the D-net on the downstream side. Disturb the substrate by kicking and brushing rocks within the 1 m ² area for 30 seconds. Material washes into the net.
4	Remove large rocks, rinse them over the net, and check undersides for invertebrates. Return rocks to their original position (face down).
5	Transfer net contents to a white sorting tray filled with stream water.
6	Sort and identify organisms using a dichotomous key. Use tweezers for delicate specimens.
7	Record each taxon and count. Note abundance category (rare, common, abundant).
8	Photograph unusual or uncertain specimens before returning all organisms to the stream — downstream of the sampling area.
9	Record habitat data: substrate type, canopy cover, bank condition, riparian vegetation, flow rate.
10	Repeat at 2–3 sample units within the reach and combine into a composite sample.

ALWAYS SAMPLE UPSTREAM TO DOWNSTREAM

Always collect your most downstream sample first, then progressively move upstream. This prevents disturbed sediment from your upstream sampling from contaminating the downstream trays you've already collected. Return organisms downstream of your current sampling position so you don't recount them.





CABIN kick net collection of benthic invertebrates, and transfer of benthic sample into a jar for later identification.

CABIN Field Manual

6. Calculating water quality from macroinvertebrate data

Once you've identified and counted your sample, several metrics can be calculated to turn raw data into a water quality assessment. Envirothon students should understand the most common approaches.

Basic scoring: the three-group method

The simplest approach counts the number of different taxa (types) found in each tolerance group. A basic formula weights sensitive taxa more heavily:

Score calculation	Interpretation
Count Group 1 taxa × 3	Each sensitive taxon contributes 3 points
Count Group 2 taxa × 2	Each somewhat tolerant taxon contributes 2 points
Count Group 3 taxa × 1	Each tolerant taxon contributes 1 point
Total score > 22	Excellent water quality
Total score 17–22	Good water quality
Total score 11–16	Fair water quality
Total score < 11	Poor water quality

EPT richness and % EPT

EPT richness = simply count the total number of different Ephemeroptera, Plecoptera, and Trichoptera taxa (species or families) found in your sample. Higher richness = better water quality.

% EPT = (Number of EPT individuals ÷ Total number of all individuals) × 100. In a healthy stream, EPT often make up 50–80% of total individuals. In an impaired stream, this may drop below 10%.

EPT : Chironomidae ratio

This CABIN metric compares sensitive EPT taxa to the tolerant midge family Chironomidae. A ratio close to 0 indicates poor water quality — mostly midges, few EPT. A ratio approaching 1 or above indicates good quality. Chironomids (midges) are often the most abundant family in any freshwater environment, so they form a reliable baseline for comparison.

7. Freshwater mussels — NB's hidden bioindicators

Freshwater mussels (family Unionidae) are bivalve molluscs that live buried in river and lake sediment. As long-lived filter feeders, they are exceptionally sensitive indicators of water quality — accumulating pollutants, responding to sedimentation and low oxygen, and depending on specific host fish for their larval (glochidia) stage. If the host fish disappears, so does the mussel — within a generation.

NB's mussel crisis

Of the eleven freshwater mussel species historically found in NB, only five are considered secure today. Two species — the Yellow Lampmussel (*Lampsilis cariosa*) and Brook Floater (*Alasmidonta varicosa*) — are listed as Special Concern under COSEWIC. The Dwarf Wedgemussel (*Alasmidonta heterodon*) is Extirpated — completely gone from NB — following the construction of the Petitcodiac causeway in 1967/68, which eliminated its American Shad host fish within weeks.

PETITCODIAC WATERSHED ALLIANCE — FRESHWATER MUSSEL PROJECT (2025)

In fall 2025, PWA staff identified over 1,000 freshwater mussels across four monitoring sites in the Petitcodiac watershed, confirming 5 different species.

The Brook Floater (*Alasmidonta varicosa*), listed as Special Concern under SARA, was among the species confirmed. In Canada, Brook Floaters are found in only a handful of rivers - making the Petitcodiac population nationally significant.

NB also has one of the only secure populations of Alewife Floater (*Utterbackiana implicata*) in North America - a conservation distinction worth knowing.

ZEBRA MUSSELS — NB'S NEWEST AQUATIC INVASIVE SPECIES THREAT

In August 2023, Zebra Mussels (*Dreissena polymorpha*) were confirmed for the first time in NB waters, found on the Madawaska River.

Zebra Mussels are devastating to native freshwater mussels - they monopolize plankton (the food source), and physically attach to native mussels in groups up to 700,000/m², smothering them. DFO and watershed groups are now implementing an Action Plan using eDNA monitoring and boat decontamination stations to limit spread in the Wolastoq (Saint John River) system.



NB freshwater mussels.

Gray Lab, UNB

8. New Brunswick spotlight

Miramichi watershed — headwater stream health

The Miramichi River watershed supports one of the world's most important Atlantic salmon populations. Salmon rely on cold, well-oxygenated headwater streams for spawning — and those streams depend on healthy riparian zones and intact macroinvertebrate communities. Stoneflies, mayflies, and caddisflies in the Miramichi headwaters are the fish food that sustains juvenile salmon through their first years of life. Logging roads, stream crossings, and riparian clearing in the watershed directly reduce EPT richness, cascading through to salmon productivity.

Wood turtles — a riparian — aquatic connection

The Wood Turtle (*Glyptemys insculpta*) is a Species at Risk in NB that illustrates the riparian–aquatic connection perfectly. It is aquatic but lays eggs in sandy upland soils near rivers and streams. PWA has conducted Wood Turtle monitoring in the Petitcodiac watershed. Wood Turtles are directly threatened by habitat loss along streams, agricultural activity in floodplains, and vehicle strikes on rural roads near rivers — all of which also degrade macroinvertebrate habitat.

ENVIROTHON EXAM TIP

You may be asked to look at a table of macroinvertebrate data and assess water quality. Work through it systematically: Are any Group 1/EPT taxa present? How many? Are Group 3 taxa dominating? Calculate the simple weighted score (Group 1 × 3 + Group 2 × 2 + Group 3 × 1). Know your key ID features for stoneflies (2 tails), mayflies (3 tails), and caddisflies (silk case / hooks).

9. Key terms

benthic macroinvertebrate Bottom-dwelling invertebrate large enough to see without a microscope; key bioindicator of stream health.	bioindicator An organism whose presence, absence, or abundance reflects environmental conditions.
EPT Ephemeroptera (mayflies), Plecoptera (stoneflies), Trichoptera (caddisflies) — the pollution-sensitive orders used in bioassessment.	EPT richness Number of different EPT taxa at a site. Higher = better water quality.
% EPT EPT individuals as a percentage of total individuals in a sample. Decreases with disturbance.	Chironomidae Midge family; most abundant in any freshwater environment; pollution-tolerant reference group in the EPT:Chironomidae ratio.
functional feeding group Classification of macroinvertebrates by food source: shredders, scrapers, collectors, filterers, predators.	shredder Macroinvertebrate that feeds on coarse particulate organic matter (CPOM) — primarily leaf litter. Dominant in headwater streams.
scraper / grazer Macroinvertebrate that feeds on periphyton (algae) growing on hard surfaces. Dominant in mid-order streams.	collector Macroinvertebrate that gathers (gatherer) or filters (filterer) fine particulate organic matter (FPOM).
CPOM Coarse Particulate Organic Matter — leaves, twigs, debris; primary energy source in headwater streams.	glochidia Parasitic larval stage of freshwater mussels; require specific host fish to complete development.
Unionidae Family of native freshwater mussels; long-lived filter feeders; among the most endangered animals in North America.	Brook Floater <i>Alasmidonta varicosa</i> ; freshwater mussel listed as Special Concern (SARA/COSEWIC); found in Petitcodiac River, NB.
Dwarf Wedgemussel <i>Alasmidonta heterodon</i> ; Extirpated from NB after Petitcodiac causeway destroyed its host fish population in 1968.	Zebra Mussel <i>Dreissena polymorpha</i> ; aquatic invasive species confirmed in NB (Madawaska River, 2023); threat to native mussels and infrastructure.
kick-net sampling Standardized CABIN field method using a D-frame net in riffle habitat; substrate disturbed by kicking for 30 seconds.	Reference Condition Approach CABIN assessment comparing observed community to undisturbed reference sites of similar physical character.


10. Quick check


Test yourself before moving on. Can you answer all of these?

Quick Check — Review Questions


1. List five reasons why benthic macroinvertebrates are better long-term bioindicators than a single chemical water quality test.
2. A stream sample contains: 3 stonefly taxa, 2 mayfly taxa, 1 caddisfly taxon (Group 1); 4 dragonfly and crayfish taxa (Group 2); 6 midge and worm taxa (Group 3). Calculate the weighted score. What water quality category does this fall into?
3. What are the key identification features that distinguish a stonefly nymph from a mayfly nymph from a caddisfly larva?
4. Explain the difference between a shredder and a collector-filterer. Where would you expect each to dominate and why?
5. The Dwarf Wedgemussel is Extirpated from New Brunswick. Trace the cause-and-effect chain from the Petitcodiac causeway to the mussel's disappearance.
6. What is the EPT:Chironomidae ratio and what does a ratio close to 0 indicate?
7. Why are freshwater mussels considered excellent bioindicators even though they are not insects?
8. BONUS: A headwater stream has had its riparian trees removed by a logging operation. Predict three specific changes to the macroinvertebrate community you would expect to observe over the following year, and explain the mechanism behind each.

11. Further resources

 **Atlas of Common Freshwater Macroinvertebrates of Eastern North America (2023)** The primary identification resource cited in the 2023 Envirothon study guide. Essential reference. *Available through academic libraries and ECCC*

 **CABIN Benthic Macroinvertebrate Metric Reference Guide** ECCC's official guide to CABIN metrics including EPT richness, % EPT, EPT:Chironomidae ratio, and more. *canada.ca/en/environment-climate-change/services/canadian-aquatic-biomonitoring-network/resources*

 **Petitcodiac Watershed Alliance — Freshwater Mussel Project** Annual mussel monitoring reports (2018–2025) in the Petitcodiac watershed. Current data on Brook Floater and other species. *petitcodiacwatershed.org*

 **Nature NB — Freshwater Mussels in NB** Overview of NB mussel species, conservation status, and UNB research programs (2023). *naturenb.ca/2023/09/28/nb-naturalist-feature-improving-our-understanding-of-freshwater-mussels-in-new-brunswick/*

 **NB Invasive Species Council — Zebra Mussel** Latest monitoring and action plan for Zebra Mussel in the Wolastoq (Saint John River) watershed. *nbinvasives.ca/zebra-mussel-info*

► **EPA Benthic Macroinvertebrates as Indicators** Clear overview of why macroinvertebrates are used as bioindicators, with good diagrams. *epa.gov/national-aquatic-resource-surveys/indicators-benthic-macroinvertebrates*

← **Previous:** Module 3: Water Quality & Monitoring

→ **Next:** Module 5: Non-Point Source Pollution