

Pollution Tolerance Index – Bag of Bugs

Adapted from: An original Creek Connections activity.
Creek Connections, Box 10, Allegheny College, Meadville, Pennsylvania 16335.

Grade Level: basic, intermediate

Duration: 45 minutes

Setting: Classroom

Summary: Students will interpret a fictitious macroinvertebrate sampling to determine water quality using a biological assessment and pollution tolerance index classification.

Objectives: Students will develop an understanding of how and why to perform a Pollution Tolerance Index, which uses macroinvertebrates to determine the health of a waterway.

Vocabulary: Macroinvertebrates, benthic, indicator organism, biodiversity, pollution tolerance index, tolerance level, sensitive, facultative, tolerant

Related Module Resources:

- Macroinvertebrate Sampling activities [binder]
- Pollution Tolerance Index Methods for field [binder]
- Various Macroinvertebrate Articles and Fact Sheets [binder]
- Books/Field Sheets
- Video: SOS For America's Streams
- Video: Creatures of the Pond
- Reference Collections
- Microscope Slides (bugs)
- Kick nets and D-frame nets

Materials (Included in Module):

- Bags of Bug Pictures [envelope]

Additional Materials (NOT Included in Module):

- None

ACADEMIC STANDARDS (ENVIRONMENT AND ECOLOGY)

7th Grade

- 4.3.7.A Identify environmental health issues.
- Identify various examples of long-term pollution and explain their effects on environmental health
- 4.3.7.C Explain biological diversity.
- Explain how diversity affects ecological integrity of the natural resources.
- 4.7.7.A Describe diversity of plants and animals in ecosystems.
- Select an ecosystem and describe different plants and animals that live there
- 4.7.7.B Explain how species of living organisms adapt to their environment
- Explain how living things respond to changes in their environment
 - Explain how one species may survive an environmental change while another might not.

10th Grade

- 4.1.10.C Describe the physical characteristics of a stream and determine the types of organisms found in aquatic environments.
- Describe and explain the physical factors that affect a stream and the organisms living there
 - Identify terrestrial and aquatic organisms that live in a watershed
 - Identify the types of organisms that would live in a stream based on the stream's physical characteristics
- 4.3.10.C Explain biological diversity as an indicator of a healthy environment.
- Explain species diversity

12th Grade

- 4.1.12.C Analyze the parameters of a watershed.
- Interpret physical, chemical and biological data as a means of assessing the environmental quality of a watershed
 - Apply appropriate techniques in the analysis of a watershed (e.g., water quality, biological diversity, erosion, sedimentation)
- 4.6.12.A Analyze the interdependence of an ecosystem
- Analyze the positive and negative impacts of outside influences on an ecosystem
- 4.6.12.C Analyze how human action and natural changes affect the balance within an ecosystem.
- Analyze effects of human action on an ecosystem.
- 4.7.12.A Analyze biological diversity as it relates to the stability of an ecosystem.
- Examine and explain what happens to an ecosystem as biological diversity changes
 - Explain the relationship between species' loss and biodiversity.

BACKGROUND:

Macroinvertebrates are organisms without internal skeletons that can be seen with the unaided eye (often considered larger than 0.5mm). Reference to the term “aquatic macroinvertebrates” can include arthropods (insects in all life cycle stages, nymph, larva, pupa, or adult or crustaceans or arachnids), mollusks, and worms. Examples of aquatic macroinvertebrates include mayfly nymphs, stonefly nymphs, dragonfly larvae, midge larvae, crayfish, leeches, aquatic worms, and water beetles. Some of these creatures are called **benthic** (bottom-dwelling) macroinvertebrates, which

means they live in, move along, or attach themselves to the waterway bottom or substrate. Not all aquatic macroinvertebrates remain on the bottom though – some swim through the water or live on the surface.

Indicator organisms are creatures that are sensitive to changes in water quality and will react to changes in their environment in predictable ways. Aquatic macroinvertebrates are one group of such organisms. Because different aquatic macroinvertebrates have different levels of tolerance to pollution, the amount of stress a stream is under can be measured by the organisms that live in that stream. Environmental degradation decreases the number of different types of organisms in a community by eliminating sensitive creatures while increasing the number of tolerant ones. This decreases the **biodiversity** (number of different forms of life) of the stream.

The **Pollution Tolerance Index** (PTI) is a means of measuring stream quality based on indicator organisms and their tolerance levels. **Tolerance levels** refer to the amount of pollution the organisms can handle before dying or moving to another habitat. By sampling a measured area of a waterway, usually a total of 3 square meters, and determining which macroinvertebrates are present and which are not, the pollution levels of a stream can be determined.

The indicator organisms are grouped into three categories based on their tolerance of pollution conditions. These categories are:

Sensitive (Group I)- The presence of sensitive organisms generally indicates good water quality because these macroinvertebrates cannot survive under polluted conditions.

Facultative (Group II)- These organisms can exist under a wider range of water quality conditions than sensitive organisms can. Therefore, they are found in fair-quality water and good-quality water.

Tolerant (Group III)- The heartiest organisms, they are tolerant of pollution. In large numbers, they point to poor water quality conditions, but can also be present in good and fair water quality.

Each of these indicator groups is assigned an index value, with the least tolerant group having the highest index value. The index score for a stream is based on the number of indicator organisms present per group.

In good-quality streams, each macroinvertebrate group should be represented, though there will probably be more sensitive organisms than tolerant or facultative organisms. Finding a worm or midge larva (both tolerant organisms) does not mean the stream is polluted, as long as the majority of the sample is from the sensitive range. However, a net full of worms and midges with no sensitive organisms will give a stream survey rating of poor.

A Pollution Tolerance Index is a common way for stream ecologists to assess the health of a waterway through biological methods. Chemical, bacterial, and land use monitoring exist as well to provide more information on the health of a stream. Although chemical tests are frequently used, they have limits that can be overcome with biological sampling.

For instance, chemical monitoring may miss a pollutant in the stream because the kit used may not include tests for that particular substance. Also, chemical testing is only a snapshot determination of stream health and pollution for that moment. Results may suggest a stream is clean even if it is polluted the other 364 days in the year.

Macroinvertebrates are subjected to day to day and longer term changes in pollution, oxygen levels, and acidity levels. With their constant contact with the water, most scientists believe that the PTI better reflects the overall condition of a stream.

OVERVIEW: Students will interpret a fictitious macroinvertebrate sampling to determine water quality using a biological assessment and pollution tolerance index classification.

PROCEDURE:

1. Separate students into at least 4 groups and distribute bug bags to each group. Share bags between groups if needed. Each bag has a different assortment of organisms in them, simulating different stream health levels. See the chart at the end of this activity for information about the contents of each bag.
2. Have each group take three *small* handfuls of bugs from their bag. This part of the activity simulates three 1 square meter kick net samples that are taken at the stream.
3. Next, have the each group sort ALL of their bugs into piles of same organism.
4. Have the students count the number of individual macroinvertebrates they have for each organism and record it on the Pollution Tolerance Index data sheet (at the end of this activity). They should record the number on the first line next to each macroinvertebrate name.

****NOTE-** There will be some extraneous bugs in the samples (and in real waterways) that are not listed on the Pollution Tolerance Index. These bugs will not be given an index ranking and will not be scored. To find out why, read the discussion section. There are also blank scraps of paper in some bags that should not be counted. ******

5. As stated on the Pollution Tolerance Index data sheet, students should assign a letter code based on each macroinvertebrate's abundance.
R (rare) = 1-9 organisms C (common) = 10-99 organisms D (dominant) = 100 + organisms
6. You may want to have students overview their data sheet and have them discuss/predict whether they have a biologically diverse stream and whether they think their stream is going to receive a healthy "score".
7. To determine the water quality rating of their stream on the back of the data sheet, students must take the total number of **letter rankings** (*not* total number of organisms) per index group and multiply it by the assigned weighting factor. The water quality score is then determined by the sums of the index values for each group.
Good >40 Fair 20-40 Poor <20

8. Have the groups share their results with the entire class.

DISCUSSION:

Make sure students are aware that this classroom simulation is an actual research procedure that they could do at a real waterway. Scientists use various types of biological assessments to determine the health of a waterway – using aquatic insects, fish, algae, and plants. There are many versions of pollution tolerance indexes used by various organizations and government agencies, but this version for aquatic insects is actually encouraged to be used by all volunteer water monitoring groups in Pennsylvania.

Why do scientists like to use aquatic macroinvertebrates to determine stream health? *See background section.*

Discuss the water quality ratings of the streams that were “sampled.” What observations do students have about the number and types of organisms in the different streams? Did streams that had many different types of organisms score better? *Yes.*

Why do they think a stream or any ecosystem is considered healthier/better quality if it has more biodiversity?

If you discover little aquatic life living in your waterway, why then is chemical testing of the water useful? *To determine the specific pollutants or poor conditions that may be in the creek and keeping aquatic creatures from living. For example, you might find out that there is too much acid, not enough dissolved oxygen, or high metal concentrations.*

Why were some organisms (such as the water strider, dragonfly larva, backswimmer) not counted in the Pollution Tolerance Index? *Not all aquatic insects are counted in the PTI because not all insects are affected directly by water pollution. Insects that live underwater and rely on it for food and breathing are only counted. So bugs that live on the water surface are not counted because they obtain their oxygen from the air. No matter how polluted the stream was or depleted of oxygen, they could still breathe and live on the water. Some insects that live underwater, such as dragonflies, are not counted because they can rise to the surface and obtain air from the atmosphere, then go back underwater. Some dragonflies even can live out of the creek or in a dry creek bed under rocks as long as there is just a little moisture. If you notice on the PTI form, many beetles that live under water are also NOT counted because they too take oxygen from the surface then go back underwater. So a polluted stream void of oxygen does not have much effect on them either.*

What problems might be causing stream pollution that negatively affects aquatic life? *(Acid rain can decrease the pH of the water to a range that some organisms cannot function at. Erosion loads sediment into a stream, creating murky water and ruining macroinvertebrate habitat. Likewise, urban areas produce runoff that can contain toxic*

chemicals and sediment. Agricultural areas may add fertilizer runoff into the stream, causing increased algal and bacterial growth. There are many other examples as well.)

EVALUATION:

- Be able to identify and name organisms that are tolerant, facultative, and sensitive.
- Explain why macroinvertebrate sampling is important for determining stream health.
- Correctly filled out Pollution Tolerance Index data sheet.

EXTENSIONS AND MODIFICATIONS:

- Use the Pollution Tolerance Index to determine the stream health value of an actual stream with the class (See “Macroinvertebrate Sampling” activity).
- Have students draw pictures of the different streams that their paper bugs samples were obtained. Encourage them to illustrate what may have caused the differences in water quality between the sites. If there stream scored badly, make sure their picture includes possible causes the reduced their stream’s biodiversity.

NOTES (PLEASE WRITE ANY SUGGESTIONS YOU HAVE FOR TEACHERS USING THIS ACTIVITY IN THE FUTURE):

Activity Version: October 2001

PTI Activity: Paper Aquatic Insects Bags of Bugs Information Sheet						
Color of Paper	Fictitious Stream Name	Quality Level of Stream	Group 1 Organisms	Group 2 Organisms	Group 3 Organisms	Extra Notes
Blue	Tionesta	Fair	4 Species No Stonefly Mayfly or Caddisfly	6 species No Damselfly or Scud	2 Species No Midge Leech, or Snail	
Yellow	Goldenrod	Poor	No Species	5 Species No Crane, Crayfish Scud, or Netspinning Caddis	5 Species (all)	
Orange	Hawkwood	Good	7 Species (all)	9 Species (all)	5 Species (all)	
Red	Rimrock	Good	7 Species (all)	9 Species (all)	5 Species (all)	
Purple	Hickory	Fair	1 Species Only Mayfly	6 species No Damselfly or Scud	3 Species No Leech or Snail	
Green	Evergreen	Good	7 Species (all)	9 Species (all)	5 Species (all)	
Brown	Tarback	Fair	No Species	9 Species (all)	5 Species (all)	
Pink	Chaney	Poor	No Species	3 Species Lots of Damselfly	3 Species	*Blank scraps do not count for anything
Peach	Richardson	Poor	No Species	3 Species Lots of Damselfly	3 Species	*Blank scraps do not count for anything
Gray	Willow	Poor	No Species	3 Species Lots of Damselfly	3 Species	*Blank scraps do not count for anything
Hot Pink	Saw Mill	Good	7 Species (all)	9 Species (all)	5 Species (all)	
Blue	Woodcock	Good	7 Species (all)	9 Species (all)	5 Species (all)	
Yellow/Orange	Thompson	Good	7 Species (all)	9 Species (all)	5 Species (all)	