26th Annual Barnegat Bay Environmental Educators Roundtable

April 19th, 2023

Utilizing Benthic Macroinvertebrates in the Classroom:

Lesson Plans & Resource List

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Introduction

Thank you for joining my workshop at the 26th Annual Barnegat Bay Environmental Educators Roundtable. In this document, you'll find a guide to replicating what we did today within the classroom. Additionally, you'll find tables recommending lessons with corresponding New Jersey Student Learning Standards for Science. Any extra materials can be found in the Appendix at the end of the document.

If links are broken or you would like any separate files sent to your email, feel free to reach out to me:

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Table I: Recommended benthic macroinvertebrate activities for grades K through 5, organized by the 2020 New Jersey Student Learning Standards for Science.

NJSLS Code	Grade	Requirements Fulfilled:	Core Ideas	Activity
K-ESS3: Earth and Human Activity	K	**K-ESS3-1** Use a model to represent the relationship between the needs of different plants or animals (including humans) and the places they live.	**ESS3.A:** Natural Resources: Living things need water, air, and resources from the land, and they live in places that have the things they need. Humans use natural resources for everything they do.	"Bugs Don't Bug Me" Coloring and Activity Book
		K-ESS3-3 Communicate solutions that will reduce the impact of climate change and humans on the land, water, air, and/or other living things in the local environment.	**ESS3.C:** Human Impacts on Earth Systems: Things that people do to live comfortably can affect the world around them. But they can make choices that reduce their impacts on the land, water, air, and other living things.	Today's Program
2-LS2: Ecosystems: Interactions, Energy, and Dynamics	2	**2-LS4-1** Make observations of plants and animals to compare the diversity of life in different habitats	**LS4.D:** Biodiversity and Humans: There are many different kinds of living things in any area, and they exist in different places on land and in water.	Today's Program could act as one habitat within a unit.
Molecules to Organisms: Structures and Processes	3	**3-LS1-1** Develop models to describe that organisms have unique and diverse life cycles, but all have in common birth, growth, reproduction, and death.	**LS1.B:** Growth and Development of Organisms: Reproduction is essential to the continued existence of every kind of organism. Plants and animals have unique and diverse life cycles.	Complete vs. Incomplete Life Cycles in Dragonflies
4-LS1: From Molecules to Organisms: Structures and Processes	4	**4-LS1-1** Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.	**LS1.A:** Structure and Function § Plants and animals have both internal and external structures that serve various functions in growth, survival, behavior, and reproduction. (4-LS1-1)	Ernie the Invertebrate, Macro Simon-Says Or "Build A Bug"
5-ESS3: Earth and Human Activity	5	**5-ESS3-1** Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources, environment, and address climate change issues.	**ESS3.C:** Human Impacts on Earth Systems: Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. Individuals and communities are doing things to help protect Earth's resources and environments.	Today's Program

Table II: Recommended benthic macroinvertebrate activities for grades 6 through 12, organized by the 2020 New Jersey Student Learning Standards for Science.

NJSLS Code	Grade	Requirements Fulfilled:	Core Ideas	Activity
MS-LS2: Ecosystems: Interactions, Energy, and Dynamics	6-8	**MS-LS2-4** Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.	**LS2.C:** Ecosystem Dynamics, Functioning, and Resilience: Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations. (MS-LS2-4) The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health. (MS-LS2-5)	Today's Program
MS-ESS3: Earth and Human Activity	6-8	**MS-ESS3-3** Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.	**ESS3.C:** Human Impacts on Earth Systems: Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. Changes to Earth's environments can have different impacts for different living things.	Today's Program
HS-LS2: Ecosystems: Interactions, Energy, and Dynamics	9-12	**HS-LS2-2** Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.	**LS2.C:** Ecosystem Dynamics, Functioning, and Resilience: A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability.	Today's Program
		HS-LS2-6 Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.		Today's Program
		HS-LS2-7 Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.	**LS2.C:** Ecosystem Dynamics, Functioning, and Resilience: Anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species.	Today's Program

Using Aquatic Macroinvertebrate Data to Estimate Stream Health

Bailey Sanders

What is a benthic macroinvertebrate?

Benthic macroinvertebrates can be explained simply by breaking down the words. Benthic means "bottom". Macro means able to be seen by the naked eye (or without a microscope). Invertebrate is an organism that does not have a backbone or spinal column. When you put it all together, you get organisms without a backbone that live at the bottom of streams and are large enough to be seen by the naked eye. Examples include but are not limited to insect larvae, crayfish, snails, and leeches! Many of the pretty bugs we know and love, like the dragonfly, start off as bugs that live in the water!

Why Benthic Macroinvertebrates?

Benthic macroinvertebrates are excellent bioindicators of stream health, due to their varied responses to pollution. They are not only easily found in a variety of environments, but they're easy to catch and can be identified using fairly simple dichotomous keys. Macros can be divided into a few major groups: Pollution Intolerant, Pollution Semi-Tolerant, and Pollution Tolerant. These groups can be seen in the table below:

Pollution Intolerant (Most Sensitive)	Pollution Semi-Tolerant (Moderately Sensitive)	Pollution Tolerant (Least Sensitive)
Caddisfly	Alderfly	Midge Larvae
Riffle Beetles & Larvae	Scuds	Black Fly Larvae
Water Penny	Damselfly	Lunged Snails
Water Snipe	Sowbug	Aquatic Worms
Mayfly	Crayfish	Leeches
Stonefly	Dragonfly	
Dobsonflies/Hellgrammites	Cranefly	
Gilled Snails	Freshwater Clams	

What is a dichotomous key and how do I use one?

A dichotomous key is a scientific tool that allows us to identify organisms using a series of questions or categories based on the physical characteristics and observable traits. The one provided in this PDF is the Stroud Research Center's Identification Guide to Freshwater Macroinvertebrates. You will start at the beginning of the key, continually referencing the organism or picture of the organism that you'd like to identify. Move through the steps and follow the page numbers it tells you to go to until you have identified the organism! **Copy and paste** the link below into your browser for a PowerPoint walkthrough of how to use a dichotomous key! Google Drive embedded links were not working properly at the time this document was made.

https://docs.google.com/presentation/d/1QLTKD3vJUdJuVeU08lN96SBcSmzQyvCm/edit?usp=sharing&ouid=117001663214224238417&rtpof=true&sd=true

This lesson plan can be tackled with three different options:

1. Using Live Macroinvertebrates Provided by your local AmeriCorps New Jersey Watershed Ambassador.
2. Using Live Macroinvertebrates that you procure on your own.
3. Using pre-made flashcards and pictures, negating the use of live macroinvertebrates.

Each of these methods has its own positives and negatives, but feel free to use the option that you gravitate to, or feel free to d some combination of the three. They are all not mutually exclusive!

Option 1: Using Live Macroinvertebrates Provided by your local AmeriCorps New Jersey Watershed Ambassador.

The New Jersey Watershed Ambassadors Program is a community-oriented AmeriCorps program designed to raise awareness about water issues in New Jersey. The NJDEP began hosting this AmeriCorps program in 2000. Through this program, AmeriCorps members are placed at local host sites in twenty (20) Watershed Management Areas (WMAs) from Sussex to Cape May counties to serve their local communities. The program works with all sectors of society to improve the quality of New Jersey's waterways, nurturing community-based environmental activities and empowering residents to make responsible and informed decisions regarding their watershed!

One of the great resources the Ambassadors provide is free presentations at schools and various local organizations on watershed education. All ambassadors are certified informal educators through the Project WET & Climate, Water, and Resilience Curriculum. Most importantly, they are trained in benthic macroinvertebrate identification and love to bring in live samples to show the kids.

Here's how to get started:

1. Look up which watershed you're in! Click here to view a map of the watershed management areas (WMAs) in New Jersey.
2. Contact your local watershed ambassador and schedule a macroinvertebrate presentation. This can be done by taking your WMA number and putting it into this email format: wma(#).njwap@gmail.com. Fill in your wma number where the # symbol is. This email format is the same for every watershed ambassador. Specify that you'd like for them to introduce how to use a dichotomous key within their presentation.
3. When the ambassador arrives on the day of the presentation, notify them that you'd like to keep a tally of the organisms you find! I suggest coming back together at the end of the presentation and doing a tally on the board or having a copy of the tally sheet that you keep for the following steps.
4. Either project the Macroinvertebrate Summary Table on the board, or have each student fill it out on their own using the tally data acquired from ambassador day.
5. Using the finished summary table, have students use the Graphing Sheet to create a bar graph showing the macroinvertebrates and the number found of each. There are pre-graphing questions, asking about which variable goes on which axis, and post-graphing questions, looking at the most common macroinvertebrate.
6. Next, we will have students attempt the biotic index. Have each student use the summary table to check off all of the organisms they saw. Each column is divided into a pollution tolerance category. Once all of the organisms are checked off, go down the column, count the number of organisms checked, and multiply the number by the number present in the box at the bottom of each column. Add the final number of each category together to produce your stream's biotic index value. Interpretation values can be used underneath the table to determine the health of your stream!
7. Come back together as a class and discuss your findings. Alternatively, this can be done together on an overhead projector.

Option 2: Using Live Macroinvertebrates that you procure on your own.

This is an option for those who don't want to have to wait on anyone else or who have a general idea of what they're doing already! Option 2 can be a combination of outdoor and indoor, or completely indoor. Pulled and modified from Utah State University, Extension, 2011.

Materials Needed:

- D-Ring Nets (Fine Mesh) OR Kick nets (see Appendix for instructions on building your own kicknet)
- Plastic containers for sorting
- Plastic Spoons
- Pipettes
- Plastic petri dishes or ice cube trays
- Magnifying glasses
- Dichotomous keys
- Buckets
- Waders or tall rain boots

How to get started:

IF YOU ARE COLLECTING MACROINVERTEBRATES FOR YOUR STUDENTS:

*******Disclaimer:*** *This will have to occur the day you plan to use the macroinvertebrates in the classroom. If you'd like to do it the evening before, you will need an aerator to keep the organisms alive, and you will have to presort the bucket to remove dragonflies and damselflies. If you neglect this step, they will eat everything in your bucket overnight. ****

1. Find a stream that you'd like to sample for macroinvertebrates. Once you've decided, bring your net, bucket, and waders/boots to the site. It is recommended that you bring someone along as a safety precaution. Add water to the bucket.
2. **If the stream bottom is gravel**, place the net so the mouth of the net is perpendicular to and facing the flow of water. Stand upstream from the net and disturb the stream bottom with your feet and hands. I like to call this the stream jig. Kick your feet into the gravel and do a little dance. Empty the contents of your net into your bucket. **If your stream is mostly sand or silt**, you can skip this step and proceed to step three.
3. Walk the length of the stream, and look for viable macroinvertebrate habitats: rocks, logs, twigs, leaf packs, vegetation that hangs into the water on the edges. Prod all of these habitats and get everything you can into your net. Scrape your net on EVERYTHING. You might not see anything right away, but you'll be surprised when you get it back to the classroom. Feel free to flip some rocks to look for caddisfly cases, black flies, leeches, etc. Empty the contents of your net into the bucket.

4. Bring your bucket of materials to the classroom. Debrief your class about benthic macroinvertebrates and how they can be used to assess the health of streams. More information on macroinvertebrates can be found in the Additional Resources section of this document. Pass out copies of the dichotomous key and conduct a demonstration on how to use it. If you need a refresher, an example can be found in the Appendix.
5. Assemble students into groups and give them containers, spoons, pipettes, and ice cube trays for sorting. Take your bucket and give each group a "scoop". Students will sort through the macroinvertebrates, trying to identify what they find, as well as keeping a tally of each. I suggest coming back together at the end of sorting and doing a class tally on the board or having a copy of the class tally sheet that you keep for the following steps.
6. Either project the Macroinvertebrate Summary Table on the board, or have each student fill it out on their own.
7. Using the finished summary table, have students use the Graphing Sheet to create a bar graph showing the macroinvertebrates and the number found of each. There are pre-graphing questions, asking about which variable goes on which axis, and post-graphing questions, looking at the most common macroinvertebrate.
8. Next, we will have students attempt the biotic index. Have each student use the summary table to check off all of the organisms they saw. Each column is divided into a pollution tolerance category. Once all of the organisms are checked off, go down the column, count the number of organisms checked, and multiply the number by the number present in the box at the bottom of each column. Add the final number of each category together to produce your stream's biotic index value. Interpretation values can be used underneath the table to determine the health of your stream!
9. Come back together as a class and discuss your findings. Alternatively, this can be done together on an overhead projector.

IF YOU ARE BRINGING STUDENTS TO COLLECT MACROINVERTEBRATES:

1. Debrief your students on safety precautions before bringing them out to the stream.
2. Explain to your students how to collect a macroinvertebrate sample.
    a. **If the stream bottom is gravel:**
        i. One student will wade into the stream and place the net so the mouth of the net is perpendicular to and facing the flow of water.
        ii. Another student will stand upstream from the net and disturb the stream bottom with his/her feet and hands.
        iii. Students can carefully pick up and rub stones directly in front of the net to remove attached animals. The stream bottom materials and organisms will be carried into the net by the current.
        iv. Tell the students to continue this process until they see no more organisms being washed into the net.

b. **If the stream bottom is sand or silt:**
    i. Students will walk the length of the stream, and look for viable macroinvertebrate habitats: rocks, logs, twigs, leaf packs, vegetation that hangs into the water on the edges.
    ii. Instruct students to prod all of these habitats and get everything you can into your net. Scrape your net on EVERYTHING. You might not see anything right away, but you'll be surprised when you get it back to the classroom.
    iii. Have other students flip some rocks to look for caddisfly cases, black flies, leeches, etc.
    iv. Empty the contents of your net into the bucket.

3. Debrief your class about benthic macroinvertebrates and how they can be used to assess the health of streams. More information on macroinvertebrates can be found in the Additional Resources section of this document. Pass out copies of the dichotomous key and conduct a demonstration on how to use it. If you need a refresher, an example can be found in the Appendix.
4. Assemble students into groups and give them containers, spoons, pipettes, and ice cube trays for sorting. Take your bucket and give each group a "scoop". Students will sort through the macroinvertebrates, trying to identify what they find, as well as keeping a tally of each. I suggest coming back together at the end of sorting and doing a class tally on the board or having a copy of the class tally sheet that you keep for the following steps.
5. Either project the Macroinvertebrate Summary Table on the board, or have each student fill it out on their own.
6. Using the finished summary table, have students use the Graphing Sheet to create a bar graph showing the macroinvertebrates and the number found of each. There are pre-graphing questions, asking about which variable goes on which axis, and post-graphing questions, looking at the most common macroinvertebrate.
7. Next, we will have students attempt the biotic index. Have each student use the summary table to check off all of the organisms they saw. Each column is divided into a pollution tolerance category. Once all of the organisms are checked off, go down the column, count the number of organisms checked, and multiply the number by the number present in the box at the bottom of each column. Add the final number of each category together to produce your stream's biotic index value. Interpretation values can be used underneath the table to determine the health of your stream!
8. Come back together as a class and discuss your findings. Alternatively, this can be done together on an overhead projector.

Option 3: Using pre-made flashcards and pictures, negating the use of live macroinvertebrates.

This option can be conducted entirely within the walls of the classroom, no live organisms needed! This lesson is conducted in groups.

Here's how to get started:

1. Debrief your class about benthic macroinvertebrates and how they can be used to assess the health of streams. More information on macroinvertebrates can be found in the Additional Resources section of this document. Pass out copies of the dichotomous key and conduct a demonstration on how to use it. If you need a refresher, an example can be found in the Appendix.
2. Print out a few copies of the Benthic Macroinvertebrate Flash Cards from the Appendix of this document. These are arranged by Stream Number*. Cut them all out.
3. Give each group a set of macroinvertebrate cards associated with a stream number. Using their dichotomous keys, have the student identify and tally all of the macroinvertebrates at their table. *Disclaimer: If you'd like to bypass the identifying altogether, there are macroinvertebrate cards that already include names in the Appendix, as well.*
4. Either project the Macroinvertebrate Summary Table on the board, or have each student fill it out on their own using the tally data acquired from ambassador day.
5. Using the finished summary table, have students use the Graphing Sheet to create a bar graph showing the macroinvertebrates and the number found of each. There are pre-graphing questions, asking about which variable goes on which axis, and post-graphing questions, looking at the most common macroinvertebrate.
6. Next, we will have students attempt the biotic index. Have each student use the summary table to check off all of the organisms they saw. Each column is divided into a pollution tolerance category. Once all of the organisms are checked off, go down the column, count the number of organisms checked, and multiply the number by the number present in the box at the bottom of each column. Add the final number of each category together to produce your stream's biotic index value. Interpretation values can be used underneath the table to determine the health of your stream!
7. Come back together as a class and discuss your findings. Alternatively, this can be done together on an overhead projector. Compare organisms found and biotic index values for each stream.

*These do not have to remain in the groups provided, if you'd like to mix and match, feel free.

If cards are kept together in the groups they were intended, here are the Biotic Index Scores for each stream:

Stream 1: Biotic Index Score = 18, Good
Stream 2: Biotic Index Score = 9, Poor
Stream 3: Biotic Index Score = 21, Excellent
Stream 4: Biotic Index Score = 13, Fair
Stream 5: Biotic Index Score = 22, Excellent
Stream 6: Biotic Index Score = 6, Poor

Appendix

1. Macroinvertebrate Summary Table
2. Macroinvertebrate Graphing Sheet
3. Macroinvertebrate Graphing Sheet Example
4. Biotic Index Worksheet
5. Biotic Index Worksheet Example
6. Additional Resources
7. Complete Vs. Incomplete Life Cycles: The Dragonfly Information
8. References
9. Photo Card References
10. Dichotomous Key
11. Macroinvertebrate Tally Sheet
12. Macroinvertebrate Table Cards
13. Bugs Don't Bug Me Useful Pages
    a. Safety tips for macroinvertebrate sampling
    b. Suggestions for teaching about aquatic invertebrates
    c. Discussion Questions
    d. Make your own Kicknet
    e. Glossary
14. Ernie the Invertebrate Activity

Name:

Date:

Macroinvertebrate Summary Table

Instructions: Using your tally sheet, fill in the summary table below. Add up all of the numbers in the second column to calculate total number of macroinvertebrates found.

Name of Macroinvertebrate	Number of Macroinvertebrates Found
Example: Mayfly	8

TOTAL NUMBER FOUND: _____

(Add up all of the numbers in the column on the right)

Name:

Date:

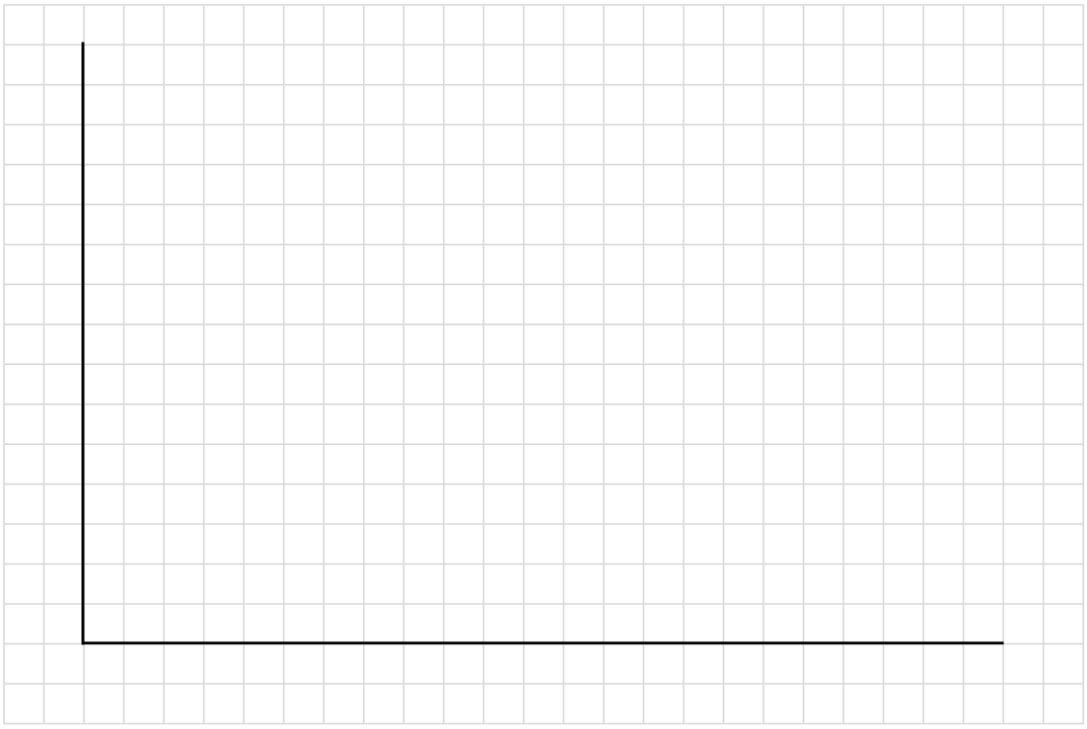
Macroinvertebrate Graphing Sheet

Instructions: Using your summary table, make a bar graph showing which macroinvertebrates you caught and how many of each you saw.

Before we graph:

1. What is going on the X-axis? _____
2. What is going on the Y-Axis? _____

Hint: Don't forget a title!



If you need more room, feel free to use a sheet of graph paper, instead!

After graphing:

1. Which macroinvertebrate was found the most? _____
2. What is their tolerance to pollution? Check the pollution-tolerance table on the biotic index sheet. _____

Name: EXAMPLE SHEET

Date:

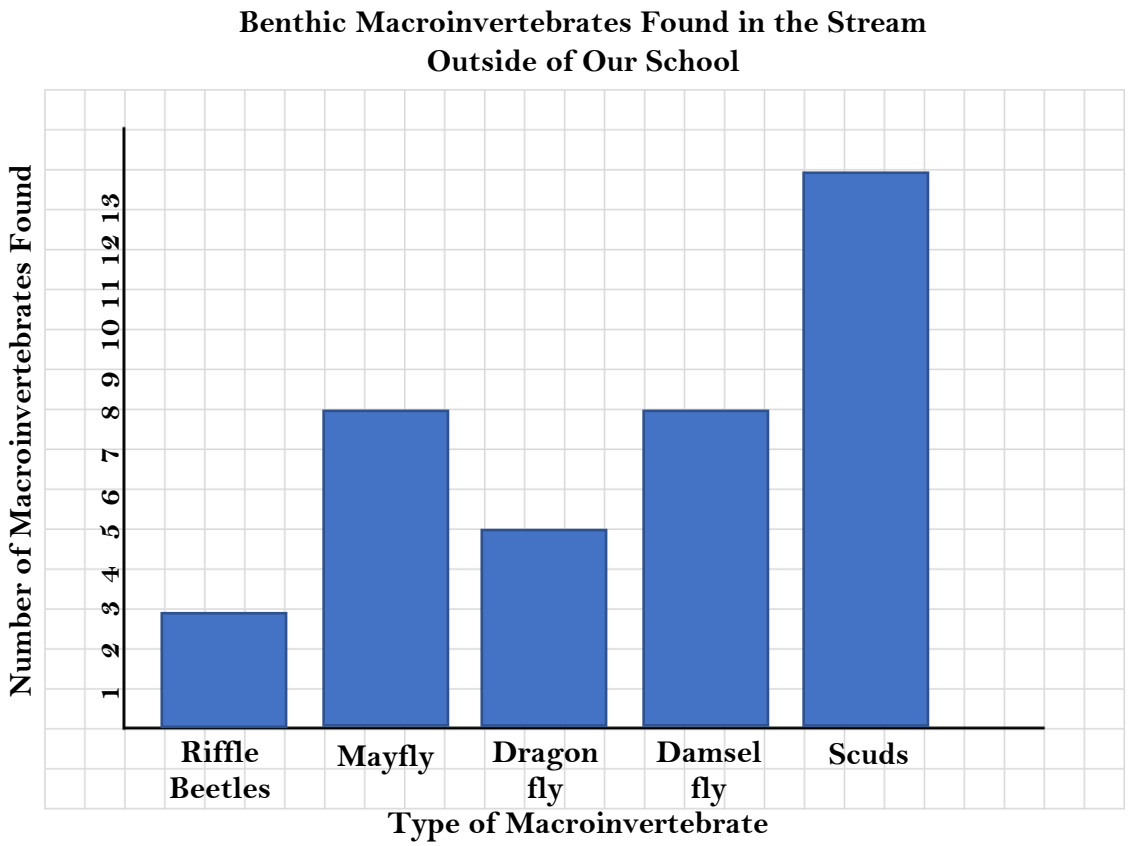
Macroinvertebrate Graphing Sheet

Instructions: Using your summary table, make a bar graph showing which macroinvertebrates you caught and how many of each you saw.

Before we graph:

1. What is going on the X-axis? Type of Macroinvertebrate
2. What is going on the Y-Axis? Number Found, Number of Macroinvertebrates Found

Hint: Don't forget a title!



If you need more room, feel free to use a sheet of graph paper, instead!

After graphing:

1. Which macroinvertebrate was found the most? Scuds
2. What is their tolerance to pollution? Check the pollution-tolerance table on the biotic index sheet. Pollution Semi-Tolerant or (Moderately Sensitive)

Name:

Date:

Biotic Index Worksheet

Instructions: Use this biotic index to calculate your stream's health. Using the data you collected, check off each organism that you saw. In each column, count up the number of organisms you checked off, and multiply it by the number in the bottom box. Add all three numbers together to get your Biotic Index Value. Based on Index found in NC Cooperative Extension Service, et al., 2009.

Pollution Intolerant (Most Sensitive)	**Pollution Semi-Tolerant (Moderately Sensitive)**	**Pollution Tolerant (Least Sensitive)**
____Case-building Caddisfly	____Alderfly	____Midge Larvae
____Riffle Beetles & Larvae	____Scuds	____Black Fly Larvae
____Water Penny	____Damselfly	____Lunged Snails
____Water Snipe	____Sowbug	____Aquatic Worms
____Mayfly	____Crayfish	____Leeches
____Stonefly	____Dragonfly	
____Hellgrammites	____Cranefly	
____Gilled Snails	____Freshwater Clams	
Total Number Checked Off: _____ x 3 =	Total Number Checked Off: _____ x 2 =	Total Number Checked Off: _____ x 1 =
_____ + _____ + _____ =		

Circle the water quality rating based on your index results:

20 or above: Excellent 15 - 19: Good 11 - 14: Fair 10 or less: Poor

*This value is just for practice. These values are not true to an official macroinvertebrate index. They should be used for practice within a classroom setting only.

Name: EXAMPLE SHEET

Date:

Biotic Index Worksheet

Instructions: Use this biotic index to calculate your stream's health. Using the data you collected, check off each organism that you saw. In each column, count up the number of organisms you checked off, and multiply it by the number in the bottom box. Add all three numbers together to get your Biotic Index Value*. Based on Index found in NC Cooperative Extension Service, et al., 2009.

Pollution Intolerant (Most Sensitive)	**Pollution Semi-Tolerant (Moderately Sensitive)**	**Pollution Tolerant (Least Sensitive)**
____Caddisfly	____Alderfly	____Midge Larvae
____Riffle Beetles & Larvae	____Scuds	____Black Fly Larvae
____Water Penny	____Damselfly	____Lunged Snails
____Water Snipe	____Sowbug	____Aquatic Worms
____Mayfly	____Crayfish	____Leeches
____Stonefly	____Dragonfly	
____Hellgrammites	____Cranefly	
____Gilled Snails	____Freshwater Clams	
Total Number Checked Off: _____ x 3 =	Total Number Checked Off: _____ x 2 =	Total Number Checked Off: _____ x 1 =
_____ + _____ + _____ =		

Circle the water quality rating based on your index results:

20 or above: Excellent 15 - 19: Good 11 - 14: Fair 10 or less: Poor

*This value is just for practice. These values are not true to an official macroinvertebrate index. They should be used for practice within a classroom setting only.

Additional Resources

Benthic Macroinvertebrate Coloring Pages INDIVIDUAL MACROS - St. John's River Water Management District

Benthic Macroinvertebrate Coloring Page – ALL

PocketMacros Identification App – Apple App Store

Pocket Macros Identification App – Google Play Store

"Bugs Don't Bug Me" Coloring and Activity Book – Utah State University, Water Quality Extension

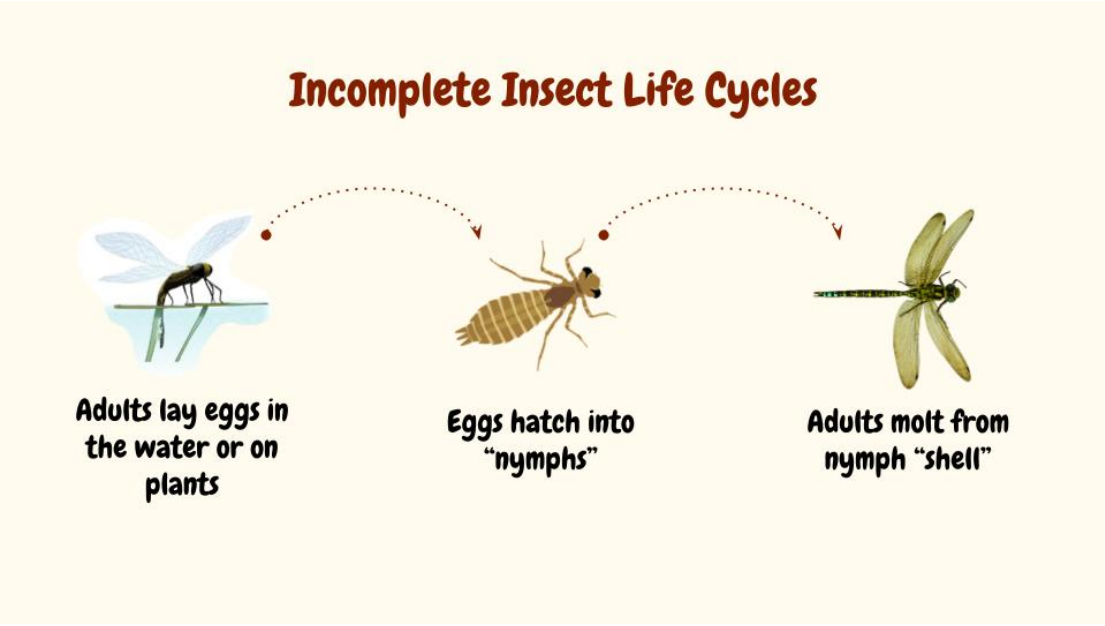
Macroinvertebrate Simon Says - Adaptations

Complete Vs. Incomplete Life Cycles: The Dragonfly

Dragonflies have incomplete life cycles, which means they go from eggs to a larval stage referred to as a nymph, and then they continuously molt until they become adults. They skip the Pupa stage. See photos and videos below.

Dragonfly molting into a larger nymph YouTube Video.

Dragonfly molting into adult with wings YouTube Video.



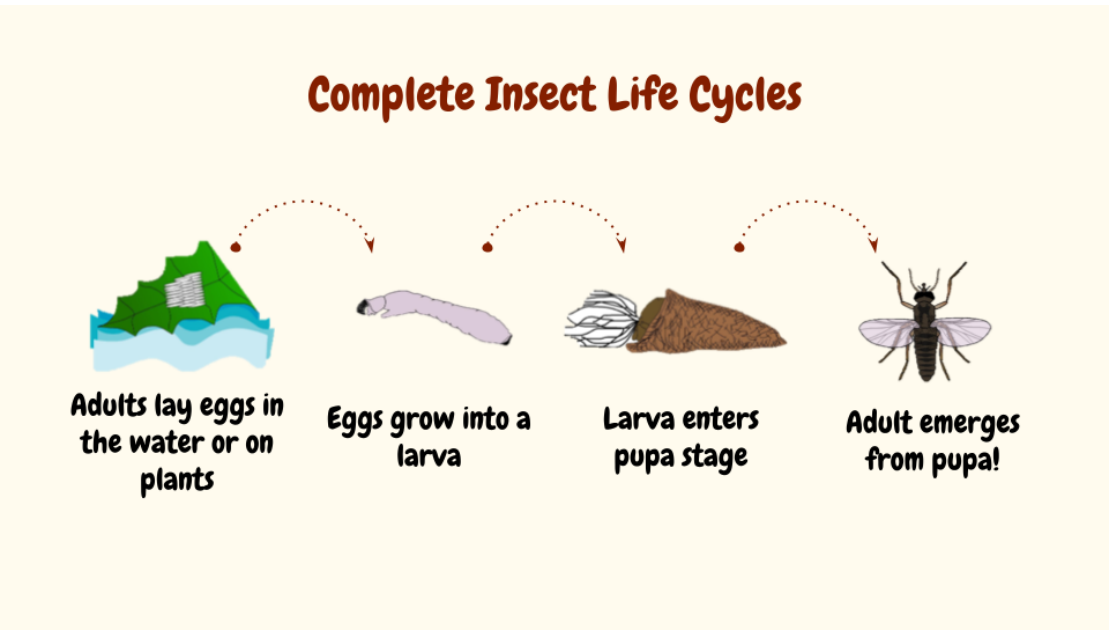


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Photo Card References

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