BIOLOGICAL & BIOMOLECULAR INTERACTIONS / BIORETS: BIOINTERACTIONS

DESIGN AND IMPLEMENTATION OF ACTIVITIES

UNIT: LIFE IN THE STREAM - MACROINVERTEBRATES

Water Quality, Biodiversity & Research

6th & 7th Grades

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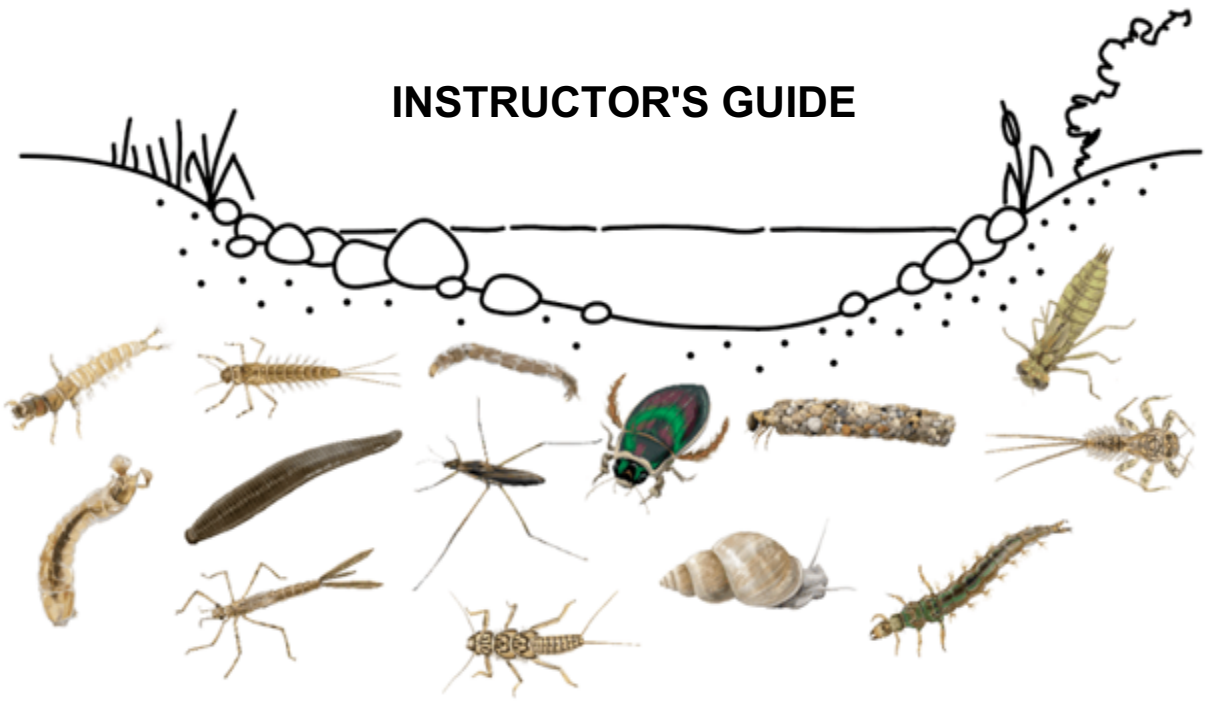
INSTRUCTOR'S GUIDE



SUBJECT: Life Science

LEVEL/GRADE: Middle School / 6th & 7th

DURATION: Two months

MAIN CONCEPTS:

A. **Biodiversity**
B. **Macroinvertebrates as bioindicators**
C. **Water quality**

SECONDARY CONCEPTS:

A. **Conservation**
B. **Habitat**
C. **Pollution**
D. **Research methods**
E. **Water parameters**

1. **Physical parameters:**
    a. dissolved oxygen (DO)
    b. pH
    c. pH range
    d. substrate
    e. turbidity
    f. water flow
    g. water temperature
2. **Chemical parameters:**
    a. heavy metal concentrations
    b. nutrient levels
    c. organic matter
3. **Biological parameters:**
    a. macroinvertebrate diversity
    b. macroinvertebrate abundance
    c. functional feeding groups

PRIOR KNOWLEDGE

The students need to have a basic knowledge of the following concepts in order to have a solid understanding of this unit. The recommended prior knowledge is listed in the table below.

General Biology	Aquatic Biology	Invertebrates	Scientific Method
Ecological systems: (formation, function, and relation with the environment). **Matter and Energy:** (interaction in an environment in terms of energy and matter). **Biodiversity:** The variety of life forms in an ecosystem (specifically, freshwater).	**Aquatic habitats:** Various types of water bodies, like streams, rivers, lakes, and oceans. **Water:** Descriptive factors affecting water bodies i.e. temperature, pH, dissolved oxygen, and nutrients.	**Characters of invertebrates:** Animals with no bones, that is, insects, worms, and crustaceans. **Basic anatomy and physiology:** Key features of invertebrate bodies and how they function.	**Observation:** process of gathering information using the senses. **Hypothesis:** A testable statement between variables. **Experimentation:** process of testing a hypothesis **Data analysis:** interpretation and evaluation of collected data. **Conclusion:** Summary of the results and whether the hypothesis is supported or refuted.

SPECIFIC LEARNING OBJECTIVES

GRADE-LEVEL STANDARDS, EXPECTATIONS, AND INDICATORS

Standards	Expectations and Indicators	NGSS Alignment	NGSS Description
Engineering and Technology	6.IT1.1 - Gathers information about the different branches of biology and associates them with related scientists and professions. 6.IT1.2 - Plans and conduct investigations with an emphasis on the correct use of experimental instruments and safety rules. 6.IT1.3 - Develops questions based on relevant data about research problems in science to define engineering problems. 6.IT1.4 - Formulates hypotheses for a research problem related to biological sciences. 6.IT1.5 - Uses the processes of observation, measurement, inference, prediction, classification, communication, data interpretation, hypothesis formulation, and experimentation, and the practices of science and engineering, in each experiment and investigation that leads them to solve problems related to the biological sciences. 6.IT1.6 - Analyzes and interprets data using tables, graphs, mathematical calculations, the International System of Units (SI), technology, and annotations, in a systematic manner, to establish clear and precise conclusions. 6.IT1.7 - Analyzes and distinguishes between useful and irrelevant data. 6.IT1.8 - Applies communication skills in preparing laboratory and experiment reports, as well as oral and written reports.	6-8 ETS1-1, ETS1-2, ETS1-3	Engineering design standards focus on problem-solving, including defining a problem, developing and testing solutions, and refining designs based on feedback.

Standards	Expectations and Indicators	NGSS Alignment	NGSS Description
	6.IT1.9 - Applies engineering practices — defines a problem, develops a solution to the problem, and optimizes the solution— considering the following aspects: - Pays attention to the precision of necessary or unnecessary criteria, as well as the limitations that could affect the possible solution to the problem. - Combines parts of different solutions to create a new solution. - Uses systematic processes to interactively test the solution to the problem and refine the solution.		
	7.IT1.2 - Applies the processes of observation, measurement, inference, prediction, classification, communication, data interpretation, hypothesis formulation, and experimentation, and the practices of science and engineering, in each experiment and investigation that leads to solving problems related to chemistry. 7.IT1.3 - Plans and conduct investigations with an emphasis on the correct use of experimental instruments, as well as the safety rules inherent to their research. 7.IT1.4 - Analyzes and interprets data through tables, graphs, mathematical calculations, use of the International System of Units (SI), use of technology, and their notes, in a systematic way, to establish clear and precise conclusions.	6-8 ETS1-1, ETS1-2, ETS1-3	Same as above, applied to chemical sciences, emphasizing experimental design and analysis.
Life Science	6.CB1.28 - Recognizes the particularities of each group of invertebrate and vertebrate animals and identifies the differences between them.	MS-LS1-1, MS-LS2-1, MS-LS2-2,	Standards focused on the understanding of living organisms, ecosystems, and the interactions within

Standards	Expectations and Indicators	NGSS Alignment	NGSS Description
	6.CB2.1 - Defines ecology and describes what an ecosystem is. 6.CB2.2 - Distinguishes the components that make up an ecosystem (organisms, populations, communities). 6.CB2.4 - Classifies and groups ecosystems, considering their natural environment (aquatic). 6.CB2.5 - Identifies and describes the ecosystems that exist in Puerto Rico and where they are located. 6.CB2.6 - Explains the ways in which one can contribute to the conservation of ecosystems in Puerto Rico. 6.CB2.8 - Distinguishes between the types of organisms that form ecosystems (producers, consumers, decomposers), considering their function within the food chain and the order in this. 6.CB2.22 - Recognizes and mentions the damage that humans cause to the environment (burning of fuels, toxic waste, deforestation, thermal pollution, among others), causing climate change that affects the structure and biodiversity of ecosystems, to give mitigation recommendations to these.	MS-LS2-4, MS-ESS3-3	and between them, including human impacts on the environment.
Physical and Chemical Sciences	7.CFQ1.1 - Conceptually defines matter, as well as the general properties that distinguish it: mass, volume, and inertia. 7.CFQ1.2 - Distinguishes and compares physical properties (intensive and extensive) and chemical properties of matter. 7.CFQ1.3 - Describes qualitative matter, including the following properties: density,	MS-PS1-1, MS-PS1-3, MS-PS1-4	Standards addressing the structure and properties of matter, chemical reactions, and the principles of physical science, including measurement and the use of scientific tools.

Standards	Expectations and Indicators	NGSS Alignment	NGSS Description
	solubility, transparency (transparent, translucent, or opaque matter), elasticity, magnetism, compressibility, and divisibility, among others. 7.CFQ1.4 - Describes quantitatively the physical properties of matter, such as mass, volume, length, density, and temperature, using the International System of Units (SI). 7.CFQ1.5 - Relates the measurements (of mass, volume, length, density, and temperature) to their corresponding units, and to the appropriate measuring instruments for each. 7.CFQ1.6 - Experiments with the magnitudes and the units of the International System of Units (SI), to calculate the density of some solids and liquids, and to highlight the importance and usefulness of this.		

CONTEXT

Biodiversity

Biodiversity, or biological diversity, is the variety of life on Earth in all its forms, from the smallest microorganisms to the largest mammals. It encompasses the genetic diversity within species, the diversity of species within ecosystems, and the diversity of ecosystems across the planet. Ecology is the scientific study of the interactions between organisms and their environments. It explores how living things, from individual organisms to entire ecosystems, interact with each other and with the non-living components of their surroundings. Biodiversity and ecology are inextricably linked. A diverse ecosystem is more resilient and better able to withstand environmental changes. The interactions between different species within an ecosystem help to maintain its balance and stability. Macroinvertebrates play a crucial role in this relationship.

Macroinvertebrates and Biodiversity

Macroinvertebrates are invertebrates (animals without backbones) that are visible to the naked eye. They include insects, crustaceans, mollusks, and worms. These organisms are essential components of aquatic ecosystems.

- Macroinvertebrates are often used as bioindicators of water quality. Their presence or absence can reveal the health of an aquatic ecosystem. A diverse community of macroinvertebrates generally indicates a healthy environment with clean water and sufficient oxygen levels.
- Macroinvertebrates provide a variety of ecosystem services, such as decomposing organic matter, filtering water, and serving as food for other organisms.
- They are an important part of the food web, providing sustenance for fish, birds, and other animals.

Macroinvertebrates

Macroinvertebrates are aquatic organisms that lack a backbone, that some can be seen without a microscope, and play a crucial role in freshwater ecosystems. They are essential components of the food web and serve as indicators of water quality and biodiversity. As primary food sources for fish, amphibians, and birds, macroinvertebrates support the overall biodiversity of aquatic ecosystems. They also contribute to nutrient cycling by breaking down organic matter and releasing nutrients into the water, which can be utilized by other organisms. Additionally, some macroinvertebrates can modify their habitats by creating shelters or altering the physical structure of the streambed.

Macroinvertebrates can be classified into different functional feeding groups, including shredders, grazers, collectors, and predators. Each group has its own unique role in the ecosystem, contributing to the overall balance and stability. Shredders break down coarse organic matter, grazers feed on algae and other fine particulate matter, collectors gather organic matter from the streambed or water column, and predators feed on other macroinvertebrates or small fish. The diversity and abundance of macroinvertebrates can be used as bioindicators to assess the health of a stream or river. They are sensitive to changes in water quality, such as pollution, habitat degradation, and disturbance. By monitoring the

presence or absence of specific macroinvertebrate species, scientists can identify sources of pollution and assess the extent of environmental damage.

Macroinvertebrates as Bioindicators

Macroinvertebrates are particularly valuable as bioindicators because they are sensitive to changes in water quality. Their presence or absence can reveal a great deal about the health of a stream or river. Different species of macroinvertebrates have varying tolerances to pollution, and by monitoring their distribution and abundance, scientists can identify sources of pollution and assess the extent of environmental damage.

The Role of Water Quality

Water quality is a crucial factor influencing the survival and distribution of macroinvertebrates. Several key water quality parameters include:

- **Dissolved oxygen (DO):** Macroinvertebrates require a certain level of dissolved oxygen in the water to survive. Low levels can indicate pollution or other environmental problems.
- **Temperature:** Water temperature affects the metabolic rates of macroinvertebrates and can influence their distribution. Extreme temperatures can be harmful to many species.
- **pH:** The acidity or alkalinity of the water can affect the availability of nutrients and the survival of macroinvertebrates.
- **Nutrient levels:** Excessive nutrients can lead to algal blooms, which can reduce dissolved oxygen levels and harm aquatic life.
- **Pollution:** Pollutants such as heavy metals, pesticides, and organic contaminants can have detrimental effects on macroinvertebrate populations.

While macroinvertebrates play crucial roles in freshwater ecosystems, the emergence of over the counter (OTC) analgesics and non-steroidal anti-inflammatory drugs (NSAIDs) poses significant threats to their health and the overall balance of these environments.

Emergence of OTC Analgesics and NSAIDs in Freshwater

Over the counter (OTC) analgesics and non-steroidal anti-inflammatory drugs (NSAIDs) are commonly used medications to alleviate pain and reduce inflammation. Unfortunately, these medications can find their way into freshwater ecosystems through various pathways, including wastewater treatment plant effluent, agricultural runoff, and direct disposal. OTC

analgesics include acetaminophen, aspirin, and ibuprofen. They are often used to treat pain associated with headaches, muscle aches, and fever. While NSAIDs, Non-steroidal anti-inflammatory drugs, include ibuprofen, naproxen, and celecoxib. They are used to reduce pain, inflammation, and fever, and are often prescribed for conditions such as arthritis and menstrual cramps. Many OTC analgesics and NSAIDs are not readily degraded by wastewater treatment processes, allowing them to enter freshwater ecosystems. Additionally, these medications are often resistant to biodegradation by aquatic plants and microorganisms, making it difficult for natural processes to remove them from the water.

Effects on Macroinvertebrates, Freshwater Ecosystems, and Humans

The presence of OTC analgesics and NSAIDs in freshwater ecosystems can have detrimental effects on macroinvertebrates, the balance of the ecosystem, and human health. These medications can disrupt the endocrine systems of macroinvertebrates, leading to reproductive problems, developmental abnormalities, and decreased survival rates. This can have cascading effects on the entire food web, as macroinvertebrates are a crucial food source for many other aquatic organisms. The presence of these pollutants can disrupt the delicate balance of freshwater ecosystems. By affecting macroinvertebrates and other aquatic organisms, they can alter food webs, nutrient cycling, and overall ecosystem health. Exposure to contaminated water can pose risks to human health, particularly for individuals who consume contaminated fish or water. Some studies have linked exposure to OTC analgesics and NSAIDs to various health problems, including gastrointestinal issues, kidney damage, and reproductive disorders.

The Need for Solutions

Imagine the ripple effect of a single painkiller tablet, washed down the drain, polluting our waterways. It’s a problem we can’t ignore. To protect our ecosystems and our own health, we need to find smarter solutions. Through the application of the scientific method, we can: understand how these medications impact our aquatic life, develop better wastewater treatment methods, and encourage alternatives that are kinder to the environment. By working together and following a rigorous scientific approach, we can create a healthier future for ourselves and the creatures that share our planet.

Glossary

1. **Biodiversity:** the variety of life forms within a given ecosystem.
2. **Conservation:** the protection and preservation of natural resources, including stream ecosystems and the macroinvertebrates they support.
3. **Dissolved oxygen (DO):** the amount of oxygen dissolved in the water is essential for the survival of aquatic organisms.
4. **Functional feeding groups:** the classification of macroinvertebrates based on their feeding habits (e.g., shredders, grazers, collectors, predators) can reveal important ecological relationships.
5. **Habitat:** the natural environment where macroinvertebrates live, including the streambed, plants, and organic matter.
6. **Heavy metal concentrations:** the presence of heavy metals can be harmful to aquatic life.
7. **Macroinvertebrate abundance:** the numbers of individuals of each macroinvertebrate species can provide information about population dynamics and habitat quality.
8. **Macroinvertebrate diversity:** the variety of macroinvertebrate species present in the stream can be an indicator of overall ecosystem health.
9. **Macroinvertebrates as bioindicators:** these organisms are sensitive to changes in water quality and their presence or absence can reveal the health of a stream.
10. **Nutrient levels:** the concentration of nutrients, such as nitrogen and phosphorus, can influence algal growth and water quality.
11. **Organic matter:** the amount of organic matter in the water can affect nutrient levels and oxygen availability.
12. **pH:** the acidity or alkalinity of the water can impact the distribution and survival of macroinvertebrates.
13. **Pollution:** the introduction of harmful substances into the environment that can negatively impact on macroinvertebrate populations and overall water quality.
14. **Research methods:** techniques used to study macroinvertebrates and assess stream health, such as sampling, identification, and analysis.

15. **Substrate:** the types of material on the stream bed (e.g., rocks, gravel, sand) can provide different habitats for macroinvertebrates.
16. **Turbidity:** the clarity of the water, which can be affected by suspended particles.
17. **Water flow:** the speed and turbulence of the water can influence habitat availability and oxygen levels.
18. **Water parameters:** the measurable characteristics of water that help determine its quality and suitability for various uses. These parameters can be physical, chemical, or biological.
19. **Water quality**: the condition of the water in a stream, including factors like dissolved oxygen levels, pH, temperature, and nutrient content.
20. **Water temperature:** the temperature of the water can affect the metabolism and distribution of macroinvertebrates.

MATERIALS PER CATHEGORY

General Laboratory Equipment

- Beakers: To mix solutions or measuring the water samples
- Forceps: Used for picking up small invertebrates
- Micropipettes: For measuring and transferring small volumes of liquids, as well picking up small invertebrates
- Trays: for placing the samples and collect macroinvertebrates
- Spring scale and bag with clip: A basic scale used for weighing shrimps.
- Magnifying glasses: For examining small organisms.
- Microscopes: For detailed observation of small macroinvertebrates
- Dissecting kits: Tools used for dissecting specimens.
- PVC mold: Used for creating specific shapes (boxes) to the heat tracking videos
- Sensors: Devices used to measure environmental parameters
- Arduino kits: Programmable electronics platforms used for creating custom devices (possible research approaches)
- Computers: For video and data analysis, create graphics and recording.

Equipment for Macroinvertebrate Studies

- Biotic index data sheets: for recording macroinvertebrate data.
- Identification key to freshwater macroinvertebrates: a guide for identifying different macroinvertebrate species.
- Preserved macroinvertebrate kits: collections of preserved macroinvertebrates for study.
- Scales (0.01g): high-precision scale for measuring very small masses.
- Solar oxygenation pump: for aerating water samples.
- Acclimation tank: for gradually adjusting organisms to new conditions.
- Water quality kit: for testing various water parameters.
- Square plastic anti-static weighing dishes: for weighing samples without static interference.
- Action camera: for underwater photography and videography.
- Light box: for illuminating specimens.
- Mini fish tank: for temporarily housing small aquatic organisms.
- Glass vials: for storing samples.

Safety Equipment

- Lab coats, gloves, and safety goggles: protective gear for students.
- Oxygen stones: used to increase dissolved oxygen in water.

Specialized Equipment (for specific experiments or labs)

- Organisms: the living subjects of the study (e.g. macroinvertebrates).
- OTC analgesics (Ibuprofen, Acetaminophen / doses from 200mg to 800mg) : a common over-the-counter pain reliever.
- Black curtains: used to control light conditions.
- LoliTrack v5: a software or program used in shrimp laboratory experiments.
- Statistical software: software used for data analysis.
- Nikon AZ100 digital microscope: a specific microscope for detailed imaging.

Software

- Microsoft Word Tools

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EDUCATIONAL PROCESS (BEGINNING, DEVELOPMENT, AND CLOSURE)

Continuous Assessment

Throughout the activities, the teacher will be systematically observing students as they work in groups, discuss, and present their findings. This ongoing assessment will involve active listening, taking notes, and asking probing questions to gauge students' understanding and identify any misconceptions. The teacher will also be providing feedback and offering guidance as needed to support students' learning. Specific observation strategies might include:

- **Individual student interactions:** Observing how students participate in group discussions, ask questions, and contribute to the activity.
- **Group dynamics:** Assessing how well students work together, share ideas, and resolve conflicts.
- **Task completion:** Evaluating students' ability to follow instructions, complete tasks, and meet deadlines.
- **Quality of work:** Assessing the accuracy, completeness, and depth of students' responses and observations.

Beginning

The activity will start by reviewing students' prior knowledge of aquatic ecosystems and macroinvertebrates.

- **Brainstorming**: Ask students create a Venn diagram of what they know about aquatic ecosystems and macroinvertebrates, and its relationship.
- **Concept mapping**: Have students to create a visual representation of their understanding of these concepts.
- **Discussion prompt and feedback opportunity**: Create a round table with students and discuss the following statements about aquatic ecosystems and macroinvertebrates. Motivates students to provide feedback on peers' responses.
- The teacher must use the **Check Mark Rubric** to evaluate the prior knowledge at the end of the module to evaluate each area.

Development

After ensuring that the teacher has clarified the prior concepts, continue with the following activity (Activity #1) to promote a deep understanding.

ACTIVITY #1: MACRO DOT DETECTIVES!

BACKGROUND: CALLING ALL CITIZEN SCIENTISTS!

Today, we become Macro Dots Detectives, using colorful clues to crack the case of water quality. Buckle up, because we're about to dive into the fascinating world of macroinvertebrates! Let's know a little bit about macroinvertebrates first.

What are Macroinvertebrates?

Macroinvertebrates are aquatic organisms that lack a backbone, that some can be seen without a microscope, and play a crucial role in freshwater ecosystems. They are essential components of the food web and serve as indicators of water quality and biodiversity. As primary food sources for fish, amphibians, and birds, macroinvertebrates support the overall biodiversity of aquatic ecosystems. They also contribute to nutrient cycling by breaking down organic matter and releasing nutrients into the water, which can be utilized by other organisms. Additionally, some macroinvertebrates can modify their habitats by creating shelters or altering the physical structure of the streambed.

Macroinvertebrates can be classified into different functional feeding groups, including shredders, grazers, collectors, and predators. Each group has its own unique role in the ecosystem, contributing to the overall balance and stability:

a. shredders - break down coarse organic matter
b. grazers - feed on algae and other fine particulate matter
c. collectors - gather organic matter from the streambed or water column
d. predators - feed on other macroinvertebrates or small fish

The diversity and abundance of macroinvertebrates can be used as bioindicators to assess the health of a stream or river. They are sensitive to changes in water quality, such as pollution, habitat degradation, and disturbance. By monitoring the presence or absence of specific macroinvertebrate species, scientists can identify sources of pollution and assess the extent of environmental damage.

OBJECTIVES:

- To identify common macroinvertebrate species found in local streams.
- To understand the concept of pollution sensitivity in macroinvertebrates.

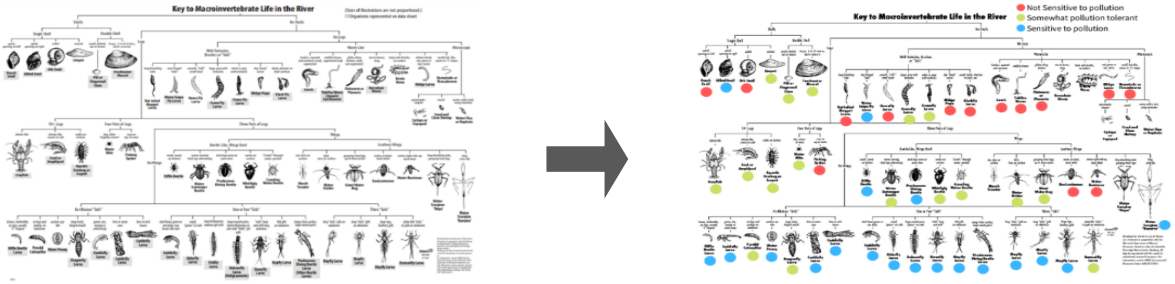
- To assess the water quality of a local stream based on the presence or absence of certain macroinvertebrates.
- To develop critical thinking and observation skills.

MATERIALS

- magnifying glasses: 20 (1 per student) - used to examine macroinvertebrates closely.
- tweezers: 20 (1 per student) - used to gently handle macroinvertebrates without harming them.
- containers for collecting macroinvertebrates: 10 (1 per group) - small plastic containers or jars to hold collected macroinvertebrates.
- macroinvertebrate key guide: 10 copies (1 per group) - a reference guide with illustrations and descriptions of common macroinvertebrate species.
- color dots (colored pencils, crayons, markers, and/or stickers)
- notebooks
- pencils
- safety attire

Preparation:

- Ensure that the stream site is accessible and safe for students. ABUNDAR SOBRE ESTO
- Gather necessary materials and distribute them to students.
- Print and review the Macroinvertebrate Key Guide for the students to familiarize them with the different species and their characteristics.
  Macroinvertebrate Key Guide Link:
  https://mdc.mo.gov/sites/default/files/mo_nature/assets/files/Life%20In%20River%20MDC%20Edits.pdf
- The images below show the Key to Macroinvertebrate Life in the River that must be printed by the teacher (left side), and the result to the pollution sensitivity assessment by the students (right side).



WORKSHEET(S): Printed Macroinvertebrate Key Guide in Legal Size Paper
https://mdc.mo.gov/sites/default/files/mo_nature/assets/files/Life%20In%20River%20MDC%20Edits.pdf

PRE-ACTIVITY SUMMARY

Introduction: Explain the importance of macroinvertebrates as indicators of water quality and biodiversity.

Sensitivity to Pollution

Macroinvertebrates are incredibly important as indicators of water quality and biodiversity due to their sensitivity to environmental changes and their position within aquatic food webs. Macroinvertebrates are highly sensitive to changes in water quality, particularly pollution levels. Different species have varying tolerances to pollutants such as chemicals (e.g., heavy metals, pesticides), nutrients (e.g., nitrogen and phosphorus), and oxygen levels (e.g., hypoxia). Some species, like mayflies, stoneflies, and caddisflies, are very sensitive to pollution and can only survive in clean, well-oxygenated water. The presence or absence of these species can provide a clear indication of water quality.

a. **Pollution-sensitive species**: These species are often found in healthy ecosystems with low pollution. Their presence suggests good water quality.
b. **Pollution-tolerant species**: Species like certain types of worms, midges, or leeches can survive in more polluted or disturbed environments. An overabundance of these species might indicate poor water quality.

Macroinvertebrates are bioindicators of water quality, as their types and numbers help scientists assess pollution levels and monitor the health of aquatic ecosystems over time.

Biodiversity and Ecosystem Health

The diversity of macroinvertebrates in a water body is a key indicator of the ecosystem's overall health and stability. Healthy ecosystems typically support a wide range of species, whereas disturbed or degraded environments often see a decline in diversity.

a. **High biodiversity**: A variety of macroinvertebrates indicates a diverse and healthy ecosystem. This diversity is essential for ecosystem services like nutrient cycling, water filtration, and the breakdown of organic matter.

b. **Low biodiversity**: A reduced number of species or a dominance of pollution-tolerant species can signal environmental stress, such as nutrient overload, habitat degradation, or contamination.

Macroinvertebrates also serve as a food source for higher trophic levels, including fish, birds, and amphibians. The diversity and abundance of macroinvertebrates directly impact the overall productivity and resilience of the aquatic food web.

Understanding Ecological Processes

Macroinvertebrates play critical roles in aquatic ecosystems, including:

a. **Decomposers**: Macroinvertebrates that feed on decomposing plant and animal matter, help break down organic material into smaller particles and release nutrients back into the water. This process supports nutrient cycling and water clarity.
b. **Food Web Support**: Macroinvertebrates are a vital food source for fish and other aquatic predators. Their diversity supports a wide range of aquatic species and contributes to the ecosystem's overall productivity.
c. **Bioaccumulation Indicators**: Since macroinvertebrates are part of the food chain, they can also serve as indicators of bioaccumulation of harmful substances, like heavy metals or pesticides, in the ecosystem.

Practical Application in Water Quality Monitoring

Macroinvertebrates are commonly used in water quality monitoring programs because they are easy to collect, identify, and analyze. Surveys of macroinvertebrates can be conducted in the field with simple tools, and the data can be used to: assess the ecological health of freshwater habitats, track changes in water quality over time, such as in response to pollution control efforts or land use changes and provide early warnings of water quality degradation, giving time for corrective actions to be taken.

Pollution sensitivity assessment: Instruct students to assign color dots to each macroinvertebrate based on its pollution sensitivity level (green, yellow, or red).

Identify Your Detectives: Use the Macroinvertebrate Key Guide (printed copy) to identify the different types of macroinvertebrates you collected. Match their physical characteristics to the pictures and descriptions in the guide.

Important Note: If you cannot collect samples from a stream, the teacher will provide some samples.

ACTIVITY #1: <u>MACRO DOT DETECTIVES!</u>

1. **Crack the Color Code:** Now for the detective work! Refer to the key below to understand what each color dot represents:
    - **Green Dot:** This macroinvertebrate is **not very sensitive** to pollution. They can tolerate some level of contamination.
    - **Yellow Dot:** This macroinvertebrate is **somewhat pollution tolerant**. They can survive in mildly polluted water but may struggle in highly polluted environments.
    - **Red Dot:** This macroinvertebrate is **very sensitive** to pollution. Their presence indicates clean, healthy water.
2. **Dot Your Detectives:** Carefully place the corresponding-colored dots on each macroinvertebrate (the ones that you collected, and the others in the printed diagram) based on its pollution sensitivity level (according to the key).
3. **Analyze the Evidence:** Look at the collection of macroinvertebrates you've classified. Are there mostly green, yellow, or red dots?
    - **Mostly Green Dots:** The stream might have some level of pollution, but it's likely not a severe issue.
    - **Mostly Yellow Dots:** The water quality might be slightly compromised.
    - **Mostly Red Dots:** Congratulations! You've found a healthy stream with clean water!

<u>Analysis of results</u>: Together, students and teacher will analyze the collected data to determine the overall health of the stream. Discuss the implications of different color dot distributions and consider potential factors affecting water quality and the environment. Use the group discussion question in the closure next.

Closure

Group discussion: The teacher will facilitate a discussion where students share their findings and analyze the overall health of the stream based on the macroinvertebrate community. Use the following questions:

a. Why are macroinvertebrates important for checking water quality?
b. How do different types of macroinvertebrates show if the water is clean or polluted?
c. What does it mean if there are a lot of different species of macroinvertebrates in a stream?
d. How do macroinvertebrates help other animals in the ecosystem?
e. Why is it important to collect and identify macroinvertebrates during water quality studies?
f. How can understanding the role of macroinvertebrates in aquatic ecosystems help us make better decisions to protect our environment?

Discussion Evaluation Rubric

Criteria	Excellent (4)	Good (3)	Fair (2)	Needs Improvement (1)
Understanding of Question	Provides a thorough, accurate, and insightful answer with a deep understanding of the topic.	Demonstrates a clear understanding but with minor gaps or less detail.	Demonstrates a basic understanding but lacks depth or clarity.	Shows limited or incorrect understanding of the question.
Engagement with the Question	Actively engages with the question, adding depth to the discussion and encouraging further exploration.	Engages with the question and responds well, but without much depth.	Responds to the question but with minimal engagement or insight.	Does not fully engage with the question or offers vague responses.
Use of Examples/Supporting Evidence	Provides clear, relevant examples or evidence that directly support the response.	Uses some relevant examples or evidence to support the response.	Uses minimal or vague examples, which may not fully support the response.	No examples or evidence are used to support the response.
Clarity and Communication	Expresses ideas clearly and logically with a well-organized response.	Ideas are mostly clear, with occasional lapses in organization or clarity.	Ideas are somewhat unclear or underdeveloped, making the response hard to follow.	Response is unclear, disorganized, or difficult to understand.
Critical Thinking and Depth	Demonstrates strong critical thinking by exploring the broader implications and connections to other ideas.	Demonstrates some critical thinking and offers thoughtful insights but lacks depth.	Shows limited critical thinking and offers basic responses that don't expand the discussion.	Offers superficial answers with no critical thinking or deeper exploration.
Ecological Awareness	Shows a deep understanding of ecological processes, emphasizing the interconnectedness of ecosystems and human impact.	Demonstrates an understanding of ecological concepts with some awareness of environmental issues.	Shows basic awareness of ecology but doesn't make clear connections to environmental impact.	Shows little to no understanding of ecological concepts or environmental issues.

Scoring Breakdown (Per Question):

- **18-24 Points:** Excellent – Thoughtful, well-supported, and ecologically aware responses that contribute meaningfully to the discussion.
- **12-17 Points**: Good – Clear and relevant responses with some ecological awareness but could use more depth or critical thinking.
- **6-11 Points**: Fair – Basic responses, with limited ecological insight or examples. Needs further engagement or clarification.
- **0-5 Points**: Needs Improvement – Lacks clear understanding or ecological awareness, offering minimal or off-topic responses.

Total Score:

- For each question (including ecological awareness), students will be scored separately, and their scores can be totaled across all questions.

How to Use:

- **Ecological Awareness:** This is integrated into each question's evaluation, assessing how well students connect their responses to broader environmental concepts and real-world implications. It is especially important when students address topics like pollution, biodiversity, and ecosystem health.
- **Final Evaluation:** A high total score reflects not only a solid understanding of the material but also active participation, critical thinking, and ecological awareness, which are essential for a deeper understanding of environmental science.

Remember: This is just a snapshot of the stream's health at a specific location and time. By repeating this activity in different areas or over time, scientists and citizen scientists like you can gather valuable data to monitor water quality and protect our precious freshwater ecosystems.

ACTIVITY #2: WATER QUALITY TESTING I & II

Continuous Assessment

The continuous assessment for the water quality testing activity involves observing students' understanding and progress throughout the learning process. In the beginning, the teacher can assess students' ability to identify different bodies of water, discuss their appearance, and draw pictures of clean and polluted environments. As the activity progresses, teachers can evaluate students' understanding of the relationship between water quality and human health, plants, and animals, as well as their ability to identify different sources of water and discuss the potential consequences of polluted water. Throughout the activity, teachers can observe students' engagement in the laboratory activities, their ability to record data accurately and completely, their ability to analyze data and draw conclusions, and their ability to communicate their findings effectively. At the end of the activity, teachers can assess students' understanding through their answers to the worksheet questions and their participation in discussions about water quality issues. By continuously assessing students throughout the activity, teachers can identify areas where students may need additional support or guidance and adjust their instruction accordingly. This will help ensure that all students have a successful learning experience.

BACKGROUND:

Water is a vital substance essential for all life on Earth. It covers approximately 71% of the planet's surface and is found in various forms, including oceans, rivers, lakes, groundwater, and ice. Water plays a crucial role in maintaining biodiversity by providing a habitat for countless species and supporting essential ecological processes. The quality of water significantly impacts the health of ecosystems and human communities. Clean water is essential for drinking, cooking, sanitation, agriculture, industry, and recreation. Pollutants can contaminate water sources, rendering them unsafe for use and harming aquatic life. Pollutants can change the quality of water in several ways. They can alter the pH level, introduce harmful chemicals, increase nutrient levels, and reduce oxygen levels. These changes can disrupt the delicate balance of aquatic ecosystems and pose risks to human health. Water pollution can be caused by various sources, including:

a. Agricultural runoff: Excess fertilizers, pesticides, and animal waste that drain into water bodies.

b. Industrial waste: Discharge of toxic chemicals and pollutants from factories and manufacturing plants.
c. Sewage: Untreated or improperly treated wastewater from homes and businesses
d. Oil spills: Accidental release of oil into water bodies, causing significant harm to marine life.

It is essential to monitor and assess water quality to ensure its safety for consumption, recreation, and environmental protection. By understanding the factors that can affect water quality and taking appropriate measures to prevent pollution, we can protect this precious resource for future generations.

OBJECTIVES:

- To understand the importance of water quality testing.
- To learn how to measure key water quality parameters using a kit: (pH, pH range, ammonia, nitrites, and nitrates) and a multiparametric water quality sensor (temperature, total dissolved solids, pH and conductivity).
- To analyze and compare water quality data from different sources.

Materials:

- Water quality testing kit (containing reagents and test tubes): 1 kit per group or pair of students. Used to measure pH, pH range, ammonia, nitrites, and nitrates in water samples. Alternate option: You can use only one kit per table and display the reagents in identified test tubes in a test tube rack. Students then add the water sample to each test tube.
- Water Quality Sensor: 1 per table- to measure temperature, TDS (Total Dissolved Solids in water), pH and conductivity.
- Calibration solutions and 4 beakers (1 set per table)
- 4 Water samples (e.g., tap water and a local water source and/or different streams): 2 samples per group or pair of students. Used for testing water quality parameters.
- Lab coat: 1 per student. Used to protect clothing from spills and stains.
- Safety glasses: 1 per student. Used to protect eyes from splashes of chemicals.
- Pen/pencil: 1 per student. Used for recording data in the data table.

- Data table: 1 per student. Used to record the measured values for each water quality parameter.
- Colored pencils and/or crayons: to color the results in the student worksheet

Preparation before the activity:

To introduce the concept of water quality, create a PowerPoint presentation featuring various images of streams in your local environment. Ask students what they can observe and whether the water appears clean or polluted.

Water quality refers to the physical, chemical, and biological characteristics of water that determine its suitability for various uses, such as drinking, recreation, and supporting aquatic life. It is essential to assess water quality because it directly affects public health, ecosystems, and industries. Poor water quality can lead to waterborne diseases, ecological damage, and issues with agricultural and industrial water use. Monitoring water quality helps ensure that water is safe for consumption, protects aquatic life, and enables the management of water resources.

To assess water quality in freshwater, several key parameters are measured, including temperature, Total Dissolved Solids (TDS), pH, and conductivity.

1. Temperature, measured in degrees Celsius (°C) or Fahrenheit (°F), indicates how hot or cold the water is. Temperature affects chemical reactions, dissolved oxygen levels, and the metabolism of aquatic organisms.
    a. Low temperatures often indicate cooler waters,
    b. High temperatures can reduce oxygen availability and stress aquatic life, promoting the growth of harmful bacteria or algae.
2. TDS (Total Dissolved Solids), measured in milligrams per liter (mg/L) or parts per million (ppm), reflects the concentration of dissolved substances such as salts, minerals, and organic compounds.
    a. Low TDS levels typically indicate very pure water, such as rainfall or mountain streams,
    b. High TDS levels may signal pollution or contamination, affecting the water's taste and the health of aquatic organisms. Extremely high TDS can be harmful

to fish and other wildlife and may require water treatment for human consumption.

3. pH is a measure of the water's acidity or alkalinity, with a scale ranging from 0 to 14, where 7 is neutral. pH affects the solubility of chemicals and the biological processes in aquatic ecosystems.
    a. Water with a pH lower than 7 is acidic, which can harm aquatic life and infrastructure,
    b. Water with pH above 7 is alkaline, which can also disrupt ecosystems and affect the availability of nutrients.
4. Conductivity, measured in micro siemens per centimeter (µS/cm) or milli siemens per centimeter (mS/cm), gauges the water's ability to conduct electricity, which is related to the concentration of dissolved ions like salts.
    a. Low conductivity indicates water with few dissolved solids, often found in clean, fresh sources.
    b. High conductivity, on the other hand, suggests a high concentration of dissolved ions, which may be due to pollution or excessive mineral content, potentially harming aquatic organisms and affecting the overall health of the water body.

WORKSHEET(S): Macroinvertebrates-Based Learning Intervention - Water Quality Testing I & II (Water Quality Test Kit and Multiparametric Sensor)

Students will record their data in the provided worksheets, complete each part, and answer the questions related to the activity in the worksheets.

1. What is the pH of samples tested?
2. How do the ammonia, nitrite, and nitrate levels compare between the two water samples?
3. How do the temperature, TDS, pH and conductivity levels compare between the tested samples?
4. Based on your data, what conclusions can you draw about the water quality of the different samples and the potential implications of the results to the environment.

Closure: Summarize the key points of the activity, emphasizing the importance of water quality testing.

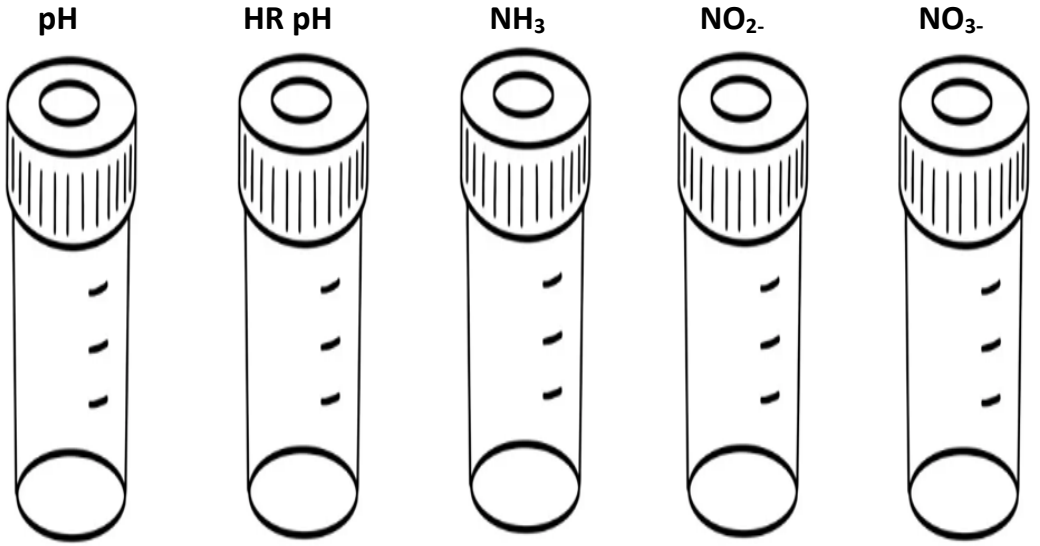
Name: _____ ____th Date: _____

Macroinvertebrates-Based Learning Intervention: Water Quality Testing I – Using a Kit Test (WORKSHEET #1)

Instructions: Employ the water quality testing kit. Conduct measurements of the water samples for the specified parameters. Document the obtained results on the table below, color the tubes, and subsequently compare the data from both water samples.

Water Sample: _____

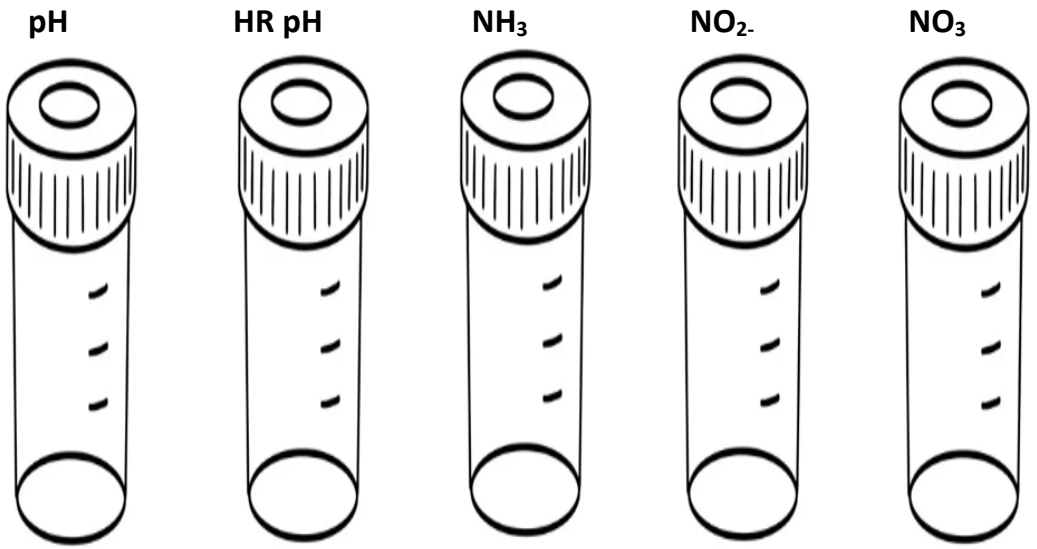
Parameter	Measurement
pH	
High Range pH	
Ammonia	
Nitrites	
Nitrates	



Conclusion:

Water Sample: _____

Parameter	Measurement
pH	
High Range pH	
Ammonia	
Nitrites	
Nitrates	



Conclusion:

Name: _____ ____th Date: _____

Macroinvertebrates-Based Learning Intervention: <u>Water Quality Testing II - Using a Multi-Parameter Sensor (WORKSHEET #2)</u>

Instructions: Measure and analyze the temperature, total dissolved solids (TDS), pH, and conductivity of different water samples using a multi-parameter sensor.

Materials:

- Multi-parameter water quality sensor
- Beaker or clean container
- Water samples from different sources (e.g., tap water, bottled water, pond water, river water)
- Data table (provided on the side)
- Safety attire (lab coat, gloves, safety glasses)

Procedure:

1. **Calibration:**
   - Calibrate the multi-parameter sensor according to the manufacturer's instructions. This is crucial for accurate readings.
2. **Sample Collection:**
   - Collect water samples from the chosen sources and pour them into clean beakers or containers.
3. **Data Collection:**
   - Turn on the multi-parameter sensor.
   - Immerse the sensor probe into the first water sample.
   - Wait for the sensor to stabilize and record the readings for temperature, TDS, pH, and conductivity in the data table.
   - Repeat steps 3 and 4 for each water sample.
4. **Data Analysis:**
   - Compare the data collected for different water samples.
   - Analyze the differences in temperature, TDS, pH, and conductivity between the samples.
   - Discuss the potential implications of the results for water quality and use.

Sample Source / Place	Temperature (°C)	TDS (ppm)	pH	Conductivity (µS/cm)
Sample 1: _____				
Sample 2: _____				
Sample 3: _____				
Sample 4: _____				

Based on your data, what conclusions can you draw about the water quality of the different samples and the potential implications of the results to the environment?

ACTIVITIES # 3, 4, 5, 6: EXPLORING MACROINVERTEBRATES WITH RESEARCH INTRO WORKSHEETS

The development phase of this part involves a set of Research Intro worksheets, each designed to engage students in hands-on exploration and scientific inquiry related to macroinvertebrates and ecosystem health.

The teacher has the flexibility to choose one of the FOLLOWING four activities as a Research Intro to perform with the students, allowing for a focused exploration of a specific topic. Alternatively, the teacher can guide students through all four activities as a comprehensive set, providing a deeper, multifaceted understanding of macroinvertebrates and their role in ecosystem health. Whether selecting a single activity or engaging with the entire series, each option is designed to enhance students' scientific inquiry and critical thinking skills.

1. **Research Intro I: Decapoda in El Yunque Tropical Rain Forest (ACTIVITY #3)**
   Students imagine themselves exploring the lush streams of El Yunque, identifying shrimp species by their scientific names, understanding their roles as filter feeders, scavengers, or predators, and learning about their classification.
2. **Research Intro II: Morphometric and Weight in Shrimps (ACTIVITY #4)**
   This activity involves students measuring the morphometric characteristics and weight of shrimp using calipers and a ziplock bag in a spring scale, helping them understand the importance of precise data collection in scientific research.
3. **Research Intro III: Macroinvertebrate Safari (ACTIVITY #5)**
   Students collect, identify, and classify macroinvertebrates from a local water body. They use their observations to assess water quality, reinforcing the concept of bioindicators in ecosystem health.
4. **Research Intro IV: Tracking the Effect of Emergent Disruptors (ACTIVITY #6)**
   In this activity, students track the effects of over-the-counter (OTC) analgesics on shrimp behavior, observing how pollutants can disrupt aquatic ecosystems.

Continuous Assessment

Throughout the activity, the teacher will observe as they move among the work groups, listen to students' discussions, and review their responses to the questions. This approach allows the teacher to assess students' learning effectively.

- **Observation:** Monitor students' participation and engagement throughout the activities. Take note of their ability to follow procedures, work collaboratively, and apply critical thinking.
- **Formative Assessments:** Utilize quizzes, oral questioning, and quick reflections to gauge students' understanding of key concepts during the lessons.
- **Feedback:** Provide timely and constructive feedback to guide students in improving their skills and knowledge.

ACTIVITY #3: RESEARCH INTRO I - DECAPODA IN EL YUNQUE TROPICAL RAIN FOREST

BACKGROUND:

El Yunque Tropical Rainforest is one of the most diverse and unique ecosystems in Puerto Rico. It is home to a wide variety of plant and animal species, including many types of shrimp, known as Decapoda. Decapods are a group of crustaceans that include shrimp, crabs, lobsters, and crayfish. In the streams of El Yunque, shrimps play crucial roles in maintaining the health of the aquatic ecosystem. They can be found hiding under rocks or leaves, where they feed on organic matter and contribute to nutrient cycling. Decapods in El Yunque are not only fascinating because of their diversity but also due to their ecological roles. Some are filter feeders, which help clean the water by removing small particles. Others are scavengers, breaking down dead organic material, while some are predators, hunting smaller organisms. Understanding the different species and their roles helps scientists monitor ecosystem health and biodiversity.

OBJECTIVES:

- Identify different species of Decapoda found in El Yunque.
- Classify shrimps based on their ecological roles (filter feeders, scavengers, or predators).
- Understand the importance of each species in maintaining the health of the stream ecosystem.

Materials:

- Field guides or identification keys (1 per student or group ??)
- Images or specimens of shrimp from El Yunque (1 set per group)
- Notebooks or worksheets for recording data (1 per student)
- Pencils and erasers (1 per student)

PROCEDURE:

1. **Review Materials:** You will be provided with identification guides and images/specimens of shrimp from El Yunque.
2. **Group Work:** In small groups, examine the identification guides and images/specimens to identify different shrimp species.
3. **Classification:** Determine whether each shrimp is a filter feeder, scavenger, or predator based on its physical characteristics and behavior.
4. **Record Data:** Use the worksheet to document the scientific names, classifications, and roles of each identified species.
5. **Discuss Findings:** Share your findings with the class and discuss the roles of different shrimp in the ecosystem.

WORKSHEET: Macroinvertebrates-Based Learning Intervention: Research Intro I
What you know about the Decapoda in El Yunque Tropical Rain Forest?

PROCEDURE

During this stage, the students' prior knowledge of the concepts to be developed is explored. This helps the teacher identify any alternative conceptions (misconceptions) that students may have and ensures they are addressed during the educational process.

- **Introduction:** Begin each lesson with a brief overview of the day's objectives, connecting the activity to previous lessons and the overall theme of macroinvertebrates and ecosystem health.
- **Engagement:** To spark curiosity and interest, start by showing the class a short video clip **(INDICAR CUAL ES)** of a polluted stream compared to a clean one. Then, pose

the following question: *"What do you think happens to the tiny creatures living in the water when the stream becomes polluted?"*

Follow this with a scenario: *"Imagine you are a scientist tasked with discovering how pollution affects the health of a stream. You've noticed that certain small creatures, like insects and shrimp, are disappearing. What could their absence tell you about the water quality?"*

Encourage students to share their thoughts and hypotheses. This discussion sets the stage for the activity where they will investigate the role of macroinvertebrates as indicators of water quality.

- **Gather Materials:** Ensure that all identification guides and images/specimens are prepared and accessible.
- **Set Up Classroom:** Arrange the classroom to facilitate group work, ensuring that students have space to examine materials.

Worksheet(s):

The worksheet will prompt students to list the shrimp species they identify, their scientific names, and their ecological roles.

Analysis of Results:

- **Discussion:** Gather the class to compare and contrast the species identified by different groups.
- **Reflection:** Ask students to write a reflection on the importance of accurate identification in research and the impact to ecological awareness. Use the rubric below to evaluate each reflection.

Reflection Rubric

Importance of Accurate Identification in Research and Ecological Awareness

Criteria	4 Exceeds Expectations	3 Meets Expectations	2 Approaching Expectations	1 Below Expectations
Reflection on Accurate Identification	The student thoroughly reflects on the importance of accurate identification in research, providing clear and detailed insights.	The student reflects on the importance of accurate identification but may lack depth or specific examples.	The student mentions accurate identification, but the reflection is vague or lacks clarity.	The student does not reflect meaningfully on the importance of accurate identification.
Connection to Ecological Awareness	The reflection clearly explains how accurate identification impacts ecological awareness and conservation efforts.	The student explains the connection between accurate identification and ecological awareness but may not explore all implications.	The student makes a limited connection between accurate identification and ecological awareness.	The student does not connect accurate identification to ecological awareness.
Depth of Reflection	The reflection demonstrates deep thinking and thoughtful analysis of the topic.	The reflection shows a basic understanding and thoughtful consideration of the topic.	The reflection is surface-level and lacks depth.	The reflection is shallow and does not demonstrate thoughtful consideration.
Clarity of Expression	The reflection is clearly written, well-organized, and easy to understand.	The reflection is mostly clear, with only minor issues in organization or clarity.	The reflection is somewhat unclear or disorganized, making it hard to fully understand.	The reflection is unclear, disorganized, or difficult to follow.

Scoring Guide:

- 12–16 points: Excellent (Student demonstrates a thorough understanding of the topic with deep reflection.)
- 8–11 points: Satisfactory (Student reflects on the topic but may lack depth or clarity.)
- 4–7 points: Needs Improvement (Reflection is surface-level and lacks clarity or depth.)
- 1–3 points: Incomplete (Student does not demonstrate understanding of the topic.)

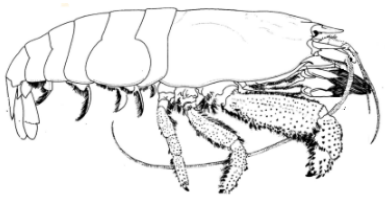
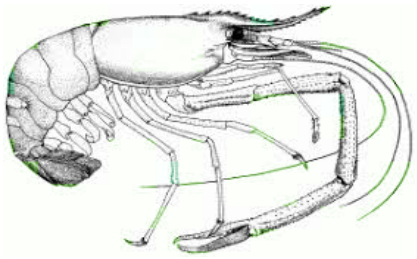
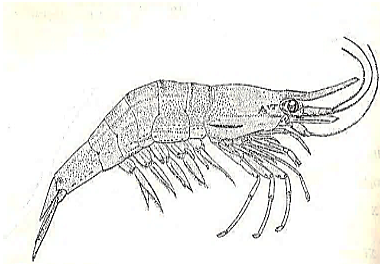
Closure:

- **Summary:** Recap the key points of the activity, emphasizing the diversity of shrimp species and their roles in the ecosystem.
- **Assessment:** Evaluate students' worksheets for accuracy and completeness.

Name: _____ ____th **Date:** _____

Macroinvertebrates-Based Learning Intervention: Research Intro I
What do you know about the Decapoda in El Yunque Tropical Rain Forest?

Instructions: Imagine yourself exploring the lush, green depths of El Yunque Tropical Rainforest. As you wade through the crystal-clear streams, keep your eyes peeled for tiny, fascinating creatures hiding beneath the rocks and leaves. These are the shrimp of El Yunque! Can you identify them by their scientific names? Are they filter feeders, scavengers, or predators? And what secrets do they hold?

	Scientific name	Classification	3 Roles in the stream
			
			
			

ACTIVITY #4: RESEARCH INTRO II - MORPHOMETRIC AND WEIGHT IN SHRIMPS

BACKGROUND: Morphometrics is the study of the size and shape of organisms and their features. In scientific research, measuring the morphometric characteristics and weight of shrimp can provide valuable insights into their health, growth, and ecological role. Shrimps are important indicators of water quality and ecosystem health, and accurate measurements are essential for understanding their biology and the impacts of environmental changes. In this activity, you will use calipers to measure the length and width of shrimp and a spring scale to determine their weight. These measurements can help scientists assess the condition of the shrimp population and make inferences about the overall health of their habitat.

OBJECTIVES:

- Measure the length, width, and weight of shrimp using appropriate tools.
- Understand the importance of these measurements in scientific research.
- Analyze the data to infer the health and growth of shrimp.

Materials:

- Calipers (1 per group)
- Ziplock bags (1 per student)
- Metal hooks (1 per group)
- Spring scales (1 per group)
- Shrimp specimens (3 per group)
- Notebooks or worksheets for recording data (1 per student)
- Pencils and erasers (1 per student)

PROCEDURE:

Preparation Before the Activity:

- **Calibrate Scales:** Ensure all spring scales are calibrated for accurate measurements.
- **Label Specimens:** Label the shrimp specimens for easy identification.

1. **Review Materials:** You will use calipers, ziplock bags, and a spring scale for this activity.
2. **Measure Shrimp:** Use calipers to measure the length and width of each shrimp. Record these measurements in the worksheet.
3. **Weigh Shrimp:** Place the shrimp in a ziplock bag and use the spring scale to measure its weight. Record this weight in the worksheet.
4. **Analyze Data:** Compare the measurements of different shrimp and discuss any patterns or variations observed.

WORKSHEET: Macroinvertebrates-Based Learning Intervention: Research Intro II
Morphometric and Weight in Shrimps

Analysis of Results:

- **Discussion:** Lead a discussion on the variation in measurements between different shrimp and what these differences might indicate about their health or role.
- **Reflection:** Encourage students to consider how these measurements could be used in ecological studies.

Closure:

- **Summary:** Review the process of taking morphometric measurements and their significance.
- **Homework:** Assign a task where students find and report on the morphometric measurements of another aquatic species.
- **Assessment:** Check the accuracy of the students' measurements and their understanding of the concepts.

Name: _____ ____th **Date:** _____

Macroinvertebrates-Based Learning Intervention: Research Intro II

Morphometric and Weight in Shrimps

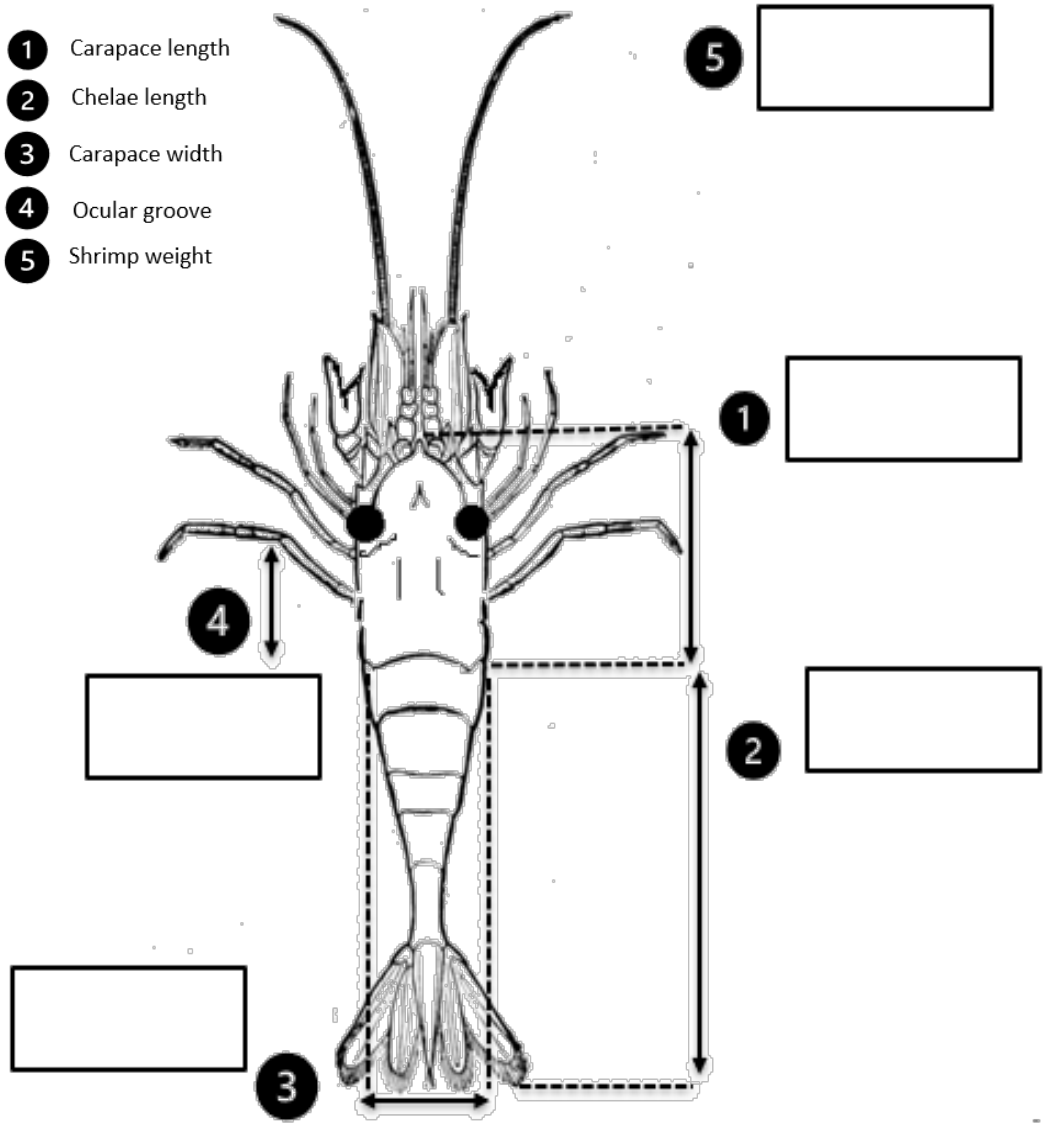
Materials:

- Caliper
- Spring balance
- Hook
- Ziplock bag
- Shrimp
- Safety attire

Instructions:

1. **Measure length and width:** Carefully grab the shrimp and with the caliper measure (in millimeters) each part. Write your measurements.
2. **Measure weight:** Attach the hook to the spring balance and the plastic bag to the hook. Weight the bag. Place the shrimp inside the bag. Read the weight measurement, subtract the bag measurement, and record it in grams.
3. **Calculate morphometric indices:** Calculate the length-to-width ratio by dividing the lengths by the width. Calculate the weight-to-length ratio by dividing the weight by the lengths.

4. **Analyze data:** Compare the morphometric measurements of your shrimp with the other tables. In your notebook, create a table and a graph with the data of all shrimps' measures.



ACTIVITY #5 : RESEARCH INTRO III - MACROINVERTEBRATE SAFARI

BACKGROUND

Macroinvertebrates are small, aquatic animals without a backbone that are visible to the naked eye. They play crucial roles in freshwater ecosystems, acting as indicators of water quality and contributing to nutrient cycling and food webs. By studying macroinvertebrates, scientists can assess the health of aquatic environments and detect changes due to pollution or habitat alteration. In this activity, you will collect, identify, and classify macroinvertebrates from a local water body. You will use their presence and diversity to assess water quality. A healthy water body typically supports a diverse community of macroinvertebrates, while pollution or other environmental stressors can reduce this diversity.

Macroinvertebrate bioassessment method involves collecting and identifying the species present in a water body, and comparing the results to established benchmarks of healthy ecosystems. The diversity and abundance of species are then used to assign a water quality score, which helps in decision-making and conservation efforts.

OBJECTIVES:

- Collect macroinvertebrates from a local water body.
- Identify and classify the collected macroinvertebrates.
- Assess water quality based on the diversity and types of macroinvertebrates found.

Materials:

- Collection nets (1 per group)
- Sorting trays (1 per group)
- Magnifying glasses (1 per student)
- Identification guides (1 per student or group)
- Notebooks or worksheets for recording data (1 per student)
- Pencils and erasers (1 per student)

Preparation Before the Activity:

- **Select Location:** Choose a safe, accessible local water body for the field trip.
- **Safety Briefing:** Prepare a safety briefing for the students.

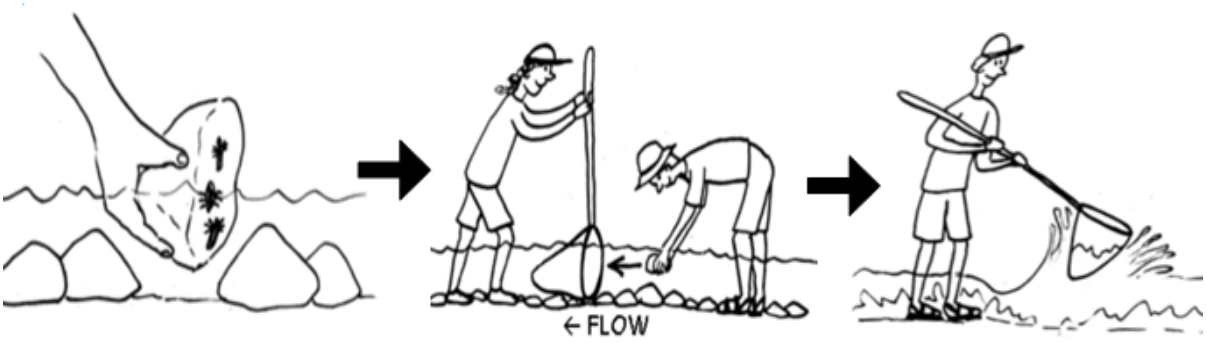
Procedure:

Summary

- **Introduction:** Discuss the role of macroinvertebrates as bioindicators of water quality.
- **Field Trip:**
    - Lead the students to the chosen water body.
    - Demonstrate how to use the collection nets and sorting trays to gather macroinvertebrates.

Field sampling: Guide students to the designated stream site and demonstrate how to collect macroinvertebrates using nets or tweezers.

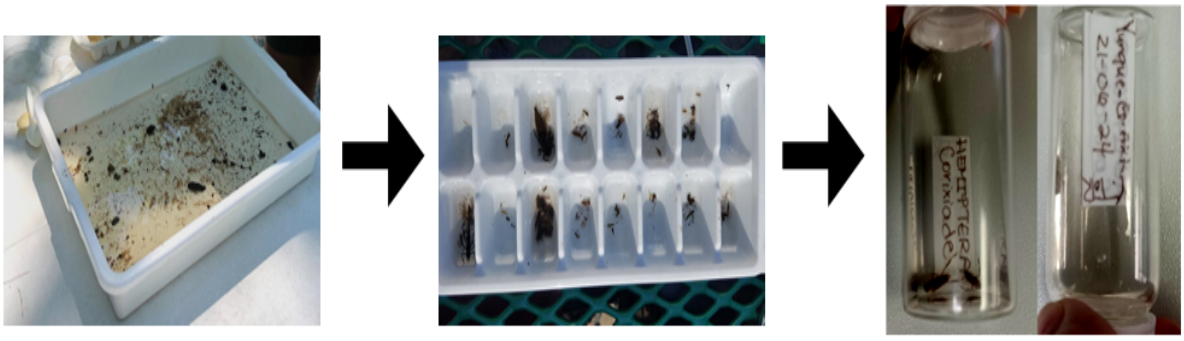
Macroinvertebrate sampling process:



To collect macroinvertebrates, start by looking under rocks in the streambed. Position the collecting net opposite to the water flow, then have the second person gently move and scratch the rocks, leaves, and substrate to dislodge the macroinvertebrates. Continue this process for about 3 minutes. Be careful not to collect branches, soil, or leaves in the net. Afterward, place the sample into a plastic bag. Label the bag with a permanent marker, label it with collector initials, collection site, and date for future reference.

Optional – You can use preserved macroinvertebrates.

- Guide students in identifying and classifying the collected specimens using the identification guides.
- **Identification:** Have students to place the sample collected in a white deep tray. Collect the macroinvertebrates in ice trays separated by species. Use the Macroinvertebrate Key Guide to identify the collected species. After separate all the organisms, place all in the sampling glass containers. Use an acid paper rectangle with an alcohol proof marker to identify the organisms by specie. See the image bellow (researcher initials, date, sampling site and scientific name.



- **Recording:** Students will document their findings in the worksheets, noting the types and quantities of macroinvertebrates found.

1. Field Collection: Use collection nets and sorting trays to gather macroinvertebrates from the water body.
2. Identification: Examine the collected specimens using identification guides and magnifying glasses.
3. Classification: Classify the macroinvertebrates based on their species and role in the ecosystem.
4. Assess Water Quality: Use the diversity and abundance of macroinvertebrates to evaluate the water quality and discuss your findings.

WORKSHEET: Macroinvertebrates-Based Learning Interventions: Research Intro III
Macroinvertebrate Safari
(Collection, Identification, and Classification of Macroinvertebrates)

Analysis of Results:

- **Discussion:** Back in the classroom, discuss the diversity of macroinvertebrates found and what it indicates about the water quality.
- **Reflection:** Ask students to reflect on the importance of biodiversity in maintaining healthy ecosystems.

Closure:

- **Summary:** Recap the key findings of the field trip and their implications for understanding ecosystem health.
- **Homework:** Assign students to research the water quality of another local body of water and compare it to their findings.
- **Assessment:** Review the accuracy and thoroughness of the students' worksheets and their ability to interpret the data.

Name: _____ ____th **Date:** _____

Macroinvertebrates-Based Learning Interventions: Research Intro III
Macroinvertebrate Safari
(Collection, Identification, and Classification of Macroinvertebrates)

Objective: Students will collect, identify, and classify macroinvertebrates from a local water body, using their observations to assess the water quality.

Materials

1. **Trays**
2. **Bucket**
3. **Scissors**
4. **Tweezers**
5. **Data sheets**
6. **Micro pipets**
7. **Microscopes**
8. **Magnifying glasses**
9. **Identification guides**
10. **Nets of different mesh sizes**
11. **Water bottles**
12. **Ethylic Alcohol**
13. **Waterproof marker (MICRON-Black), acid paper and glass sampling containers**
14. **Protective attire (In classroom: lab coat, gloves and safety glasses)**
15. **Safety waders and gloves (optional – for sampling on water bodies)**

Procedure

For sampling in the water body (On Site):

1. **Safety First:** Discuss safety precautions with students, such as wearing appropriate footwear, avoiding areas with strong currents, and being aware of potential hazards.
2. **Choose a Location:** Select a nearby stream, pond, or river. Ensure that it is a safe and accessible location.
3. **Collect Samples:**

- Use nets of different mesh sizes to collect macroinvertebrates from various habitats within the water body (e.g., bottom sediments, vegetation, water column).
- Transfer the collected organisms to the bucket filled with water.

In the classroom:

4. **Identification and Classification:**

   - Divide the sample collected in the trays.
   - Use the water bottle to wash and remove the leaves, rocks, and pieces of woods from the tray.
   - Using magnifying glasses and identification guides, students will group the macroinvertebrates.
   - With the tweezers and/or the micro pipet, group the macroinvertebrates based on their physical characteristics and taxonomic classification.
   - Use the microscope to assure your classification and to identify smaller organisms.
   - Identify the macroinvertebrates they have collected.
   - Cut small rectangles of the acid paper.
     ID Key to write on the paper: Date/Place/ Person / Macro ID
   - Place the ID key inside the glass sampling containers, with the macroinvertebrates of the same group.
   - Fill the glass containers with the ethylic alcohol.
   - Record the findings on the data sheets, including the number of individuals, species identified, and any noticeable characteristics.
   - Use the data to assess the overall health of the water body.

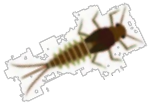
5. **Data Analysis:**

   - Discuss the types of macroinvertebrates found.
   - Create a class chart or graph to visualize the results.
   - Take the bucket to the classroom.

Name: _____ ____th Date: _____

Macroinvertebrates-Based Learning Interventions
Macroinvertebrate Safari - Data Sheet

Sample Location:		Date:		Time:
Macroinvertebrate [Species]	**Quantity [Number]**	**Tolerance to Pollution**		
		Sensitive	**Somewhat sensitive**	**Tolerant**
Add sensitive ____ + somewhat sensitive ____ + tolerant ____ = ____ Water Quality Rating		**Number of checkmarks: ___ times 3 = ___**	**Number of checkmarks: ___ times 2 = ___**	**Number of checkmarks: ___ times 1 = ___**



Water Quality Rating (check one)

____ Excellent (>22) ____ Good (17 – 22) ____ Fair (11 – 16) ____ Poor (<11)

ACTIVITY # 6: RESEARCH INTRO IV - TRACKING THE EFFECT OF EMERGENT DISRUPTORS (Optional – For Students interested in Research and / or Science Fair)

BACKGROUND:

Emergent disruptors are substances that enter aquatic ecosystems and can impact the health of aquatic organisms. Over the counter (OTC) analgesics, such as acetaminophen, are examples of these disruptors. When these chemicals are present in water bodies, they can affect the behavior and health of aquatic organisms, including shrimp. Studying these effects helps scientists understand the broader impacts of pollution on ecosystems. In this activity, you will observe how different concentrations of OTC analgesics affect shrimp behavior. By tracking these changes, you will learn about the potential risks posed by pollutants and the importance of monitoring and managing chemical contaminants in aquatic environments.

OBJECTIVES:

- Observe and record the behavior of shrimp exposed to different concentrations of OTC analgesics.
- Analyze how these substances impact shrimp health and behavior.
- Understand the implications of chemical pollutants on aquatic ecosystems.

Materials:

- Shrimp specimens (2 per group)
- Tanks or containers for shrimp (1 per group)
- OTC analgesics (e.g., acetaminophen) in varying concentrations
- Observation sheets (1 per student)
- Pencils and erasers (1 per student)

PROCEDURE

Preparation Before the Activity:

- **Set Up Tanks:** Prepare tanks or containers with water and ensure that shrimp are acclimated.

- **Prepare Solutions:** Create solutions of OTC analgesics at different concentrations.

1. Construct the dark Recording Station (PVC stands, cameras, light mat, red acrylic box, black curtains and timer)
2. Identify the Tanks: Label the tanks as "Control" and "Experimental."
3. Prepare Water: Fill each tank with three cups of water.
4. Set Up Oxygenation: Install and set up the oxygenation devices in each tank.
5. Measure Water Quality (Control): Measure and record the water quality parameters (e.g., pH, temperature, dissolved oxygen) for the control tank.
6. Prepare Analgesic Solution: Weigh the amount of OTC analgesic using the weighting plate and weight machine.
7. Add Analgesic: Add the measured OTC analgesic to the experimental tanks.
8. Place Shrimp: Introduce shrimp into the tanks with water containing different concentrations of OTC analgesics.
9. Observation: Monitor and record the behavior of the shrimp over time (5 minutes with a mini camera in the dark station), noting any changes or abnormal behaviors.
10. Recording Data: Use the worksheet to document your observations and any patterns in behavior.
11. Discussion: Discuss your findings with the class and consider the broader implications for water quality and ecosystem health.

WORKSHEET:

- Concentration of OTC Analgesic
- Behavior Observed (e.g., inactivity, unusual swimming patterns)
- Implications for Water Quality

Closure:

Discussion: Analyze the observed behavior changes in shrimp across different concentrations. Discuss the broader implications for ecosystems and human health.

Reflection: Encourage students to think critically about how human activities can impact the environment and what steps can be taken to mitigate these effects.

- **Summary:** Summarize the findings and discuss the importance of monitoring and managing emergent disruptors in water systems.
- **Homework:** Assign a research project on another potential emergent disruptor and its effects on aquatic life.
- **Assessment:** Evaluate the students' ability to conduct experiments, analyze data, and draw conclusions based on their observations.

Name: _____ ____th Date: _____

Macroinvertebrates-Based Learning Intervention: Research Intro IV

Lolli Tracking the Effect of Emergent Stressors in Fresh Water

Objective: To investigate how different concentrations of over-the-counter (OTC) analgesics affect the behavior of shrimp in freshwater. You will compare shrimp behavior in experimental tanks with varying levels of analgesics and observe any changes through video recordings.

Part 1: Setup

1. Tank Identification	**Control Tank: Yes / No** **Experimental Tank 1: Yes / No** **Experimental Tank 2: Yes / No**
2. Water Preparation	**Amount of Water in Each Tank: 3 cups in each tank** **Yes / No**
3. Oxygenation Devices	**Device Setup Completed in each tank** **Yes / No**

4. Water Quality Measurement **Control Tank Measurements:** **a. pH: _____** **b. Temperature (°C): _____** **c. Dissolved Oxygen (mg/L): _____** **d. Conductivity (µS/cm): ____**	**Experimental Tank 1 Measurements (with the OTC)** **a. pH: _____** **b. Temperature (°C): _____** **c. Dissolved Oxygen (mg/L): _____** **d. Conductivity (µS/cm): ____**
	Experimental Tank 2 Measurements (with the OTC) **a. pH: _____** **b. Temperature (°C): _____** **c. Dissolved Oxygen (mg/L): _____** **d. Conductivity (µS/cm): ____**
5. Analgesic Preparation	**Analgesic Type: OTC Analgesic _____** **Concentration of OTC Analgesic** **a. Control Tank: 0 g/L** **b. Experimental Tank 1: _____ g/L** **c. Experimental Tank 2: _____ g/L**
6. Behavioral Observation	**Video Recording Started: Yes / No** **Observation Period: _____ minutes**

Part 2: Observations

1. **Behavior Observed (Based on Video Recordings):**
    a. **Control Tank:**
        - **Normal Behavior: Yes / No**
        - **Abnormal Behavior: Yes / No**
        - **Description of Behavior: _____**
    b. **Experimental Tank 1:**
        - **Normal Behavior: Yes / No**
        - **Abnormal Behavior: Yes / No**
        - **Description of Behavior: _____**
    c. **Experimental Tank 2:**
        - **Normal Behavior: Yes / No**
        - **Abnormal Behavior: Yes / No**
        - **Description of Behavior: _____**

Part 3: Analysis

1. **Comparative Analysis: Describe any differences in shrimp behavior between the control tank and the experimental tanks:**

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2. **Implications for Water Quality: Based on your observations, how might the presence of OTC analgesics affect water quality and the health of aquatic ecosystems?**

3. **Implications for the Macroinvertebrate: Based on your results, is there any death rate during your experimental process?**

Reflection:

- **What did you learn about the impact of OTC analgesics on shrimp behavior?**

- **How could this experiment be improved or extended in future studies?**

Last Question: Ecological Awareness Check

To wrap up encourages students to reflect on both their learning from the specific experiment and how it connects to broader ecological concepts. Encourage students to assess how their involvement in the experiment connects to broader environmental issues.

Please check all that apply to indicate the elements of ecological awareness you gained from this activity:

Item	No	Yes
I recognize how human-made chemicals (like OTC analgesics) can affect aquatic ecosystems.		
I understand the importance of water quality parameters (pH, temperature, dissolved oxygen, conductivity) in the health of aquatic life.		
I can identify the role of macroinvertebrates as bioindicators of water quality.		
I learned that even low concentrations of pollutants can have significant effects on organisms.		
I have a deeper appreciation for how human activities impact freshwater ecosystems.		
I understand the need for responsible disposal and regulation of pharmaceuticals to protect water quality.		
I recognize the potential cumulative effects of environmental stressors on aquatic species.		
I learned that experimental design and behavioral observations can help assess environmental impacts.		

Teacher's Comments:

STUDENT ACTIVITY & ECOLOGICAL AWARENESS CHECKLIST RUBRIC

This rubric can be used to assess students' engagement in ACTIVITY #1 through ACTIVITY #6, as well as their reflection on the Importance of Accurate Identification in Research and Ecological Awareness.

Name: _____ **Date:** _____

Criteria	Yes	No	Comments
ACTIVITY #1: MACRO DOT DETECTIVES! (Group Discussion Evaluation)			
Active Participation in Group Discussion	[ ]	[ ]	Did the student actively participate in the group discussion on macroinvertebrates?
Identification of Macroinvertebrates	[ ]	[ ]	Did the student identify key macroinvertebrates and their role in the ecosystem?
Ecological Awareness: Linking to Water Quality	[ ]	[ ]	Did the student explain how the presence of different macroinvertebrates is indicative of water quality?
Collaboration and Teamwork	[ ]	[ ]	Did the student collaborate effectively with peers during the activity?
ACTIVITY #2: Macroinvertebrates-Based Learning Intervention - Water Quality Testing I (Water Quality Test Kit)			
Proper Use of Water Quality Test Kit	[ ]	[ ]	Did the student use the water quality test kit correctly?
Accurate Recording of Results	[ ]	[ ]	Did the student accurately record test results (e.g., pH, turbidity)?
Understanding of Water Quality Parameters	[ ]	[ ]	Did the student understand and explain the significance of the water quality parameters tested?
Link Between Water Quality and Ecosystem Health	[ ]	[ ]	Did the student connect the test results to the health of the ecosystem, particularly the macroinvertebrate populations?
ACTIVITY #2: Macroinvertebrates-Based Learning Intervention - Water Quality Testing II (Multiparametric Sensor)			
Proper Use of Multiparametric Sensor	[ ]	[ ]	Did the student use the multiparametric sensor appropriately?
Interpretation of Sensor Data	[ ]	[ ]	Did the student interpret sensor data (e.g., dissolved oxygen, temperature) accurately?
Critical Thinking: Sensor vs. Traditional Methods	[ ]	[ ]	Did the student compare and contrast sensor-based testing with traditional methods?
Connection to Ecological Health	[ ]	[ ]	Did the student explain how sensor data reflects the overall health of the ecosystem?
ACTIVITY #3: Research Intro I - Decapoda in El Yunque Tropical Rain Forest			
Understanding of Decapoda Ecology	[ ]	[ ]	Did the student demonstrate a clear understanding of Decapoda and their role in tropical rainforest ecosystems?
Application of Ecological Principles	[ ]	[ ]	Did the student apply ecological principles to explain Decapoda's ecological significance?
Research Design and Methodology	[ ]	[ ]	Did the student show understanding of the research methods related to studying Decapoda?
Link to Conservation Efforts	[ ]	[ ]	Did the student connect Decapoda research to broader conservation efforts in El Yunque?

Criteria	Yes	No	Comments
Reflection Rubric: Importance of Accurate Identification in Research and Ecological Awareness			
Reflection on Accurate Identification	[ ]	[ ]	Did the student reflect on why accurate species identification is crucial in ecological research?
Connection to Ecological Awareness	[ ]	[ ]	Did the student discuss how accurate identification promotes better understanding of ecosystems?
Depth of Reflection	[ ]	[ ]	Did the student demonstrate critical thinking and provide thoughtful analysis in their reflection?
Clarity of Expression	[ ]	[ ]	Was the student's reflection clearly written and well-organized?
ACTIVITY #4: Research Intro II - Morphometric and Weight in Shrimps			
Understanding of Morphometry in Shrimp	[ ]	[ ]	Did the student understand how morphometric data is used in research on shrimp?
Accurate Data Collection and Analysis	[ ]	[ ]	Did the student correctly collect and analyze morphometric data on shrimp?
Link Between Shrimp Morphology and Ecology	[ ]	[ ]	Did the student explain how shrimp morphology impacts their ecological role?
ACTIVITY #5: RESEARCH INTRO III - Macroinvertebrate Safari			
Active Participation in Macroinvertebrate Safari	[ ]	[ ]	Did the student actively participate in identifying and observing macroinvertebrates?
Understanding of Macroinvertebrate Roles	[ ]	[ ]	Did the student demonstrate an understanding of the role macroinvertebrates play in the ecosystem?
Connection to Water Quality and Ecosystem Health	[ ]	[ ]	Did the student link their observations to water quality and the overall health of the ecosystem?
ACTIVITY #6: Research Intro IV - Tracking the Effect of Emergent Disruptors (Optional for interested students in Science Fair)			
Understanding of Emergent Disruptors	[ ]	[ ]	Did the student show understanding of what emergent disruptors are and how they affect ecosystems?
Data Collection on Disruptors' Impact	[ ]	[ ]	Did the student correctly collect and analyze data related to the impact of disruptors?
Discussion of Ecological Impact	[ ]	[ ]	Did the student discuss the potential ecological impacts of emergent disruptors, especially on aquatic ecosystems?
Overall Ecological Awareness			
Link Between Research and Ecological Conservation	[ ]	[ ]	Did the student demonstrate an understanding of how their research activities support broader ecological conservation efforts?
Ability to Apply Ecological Concepts in Field Work	[ ]	[ ]	Did the student effectively apply ecological concepts during fieldwork and research activities?
Critical Thinking and Problem Solving	[ ]	[ ]	Did the student demonstrate the ability to think critically and solve problems related to ecological research?

Scoring Guide:

- Yes (checkmark) indicates that the student has successfully met the criteria.
- No (blank) means the student did not meet the criteria or needs further development.

- After completing the checklist, the teacher can assign a numerical score based on the number of "Yes" responses to provide an overall evaluation of the student's participation, ecological awareness, and research skills:
- **15-20 Yes responses**: Excellent engagement, deep understanding of ecological principles, and strong research skills.
- **10-14 Yes responses**: Good participation and understanding, but with areas for improvement in ecological awareness or research practices.
- **5-9 Yes responses**: Satisfactory understanding with some gaps in knowledge or application of research concepts.
- **0-4 Yes responses**: Needs significant improvement in participation, understanding, and application of ecological principles

Module - Closing

The activity will start by reviewing students' acquired knowledge of aquatic ecosystems and macroinvertebrates.

- **Brainstorming**: Ask students to create a Venn diagram of what they know about aquatic ecosystems and macroinvertebrates, and its relationship.
- **Concept mapping**: Have students create a visual representation of their understanding of these concepts.
- **Discussion prompt and feedback opportunity**: Create a round table with students and discuss the following statements about aquatic ecosystems and macroinvertebrates, Motivates students to provide feedback on peers' responses.
- The teacher must use Check **Mark Rubric** to evaluate knowledge acquired at the end of all activities in the module.

Module (Beginning and Closing) - Check Mark Rubric

1. **Brainstorming: Venn Diagram of Aquatic Ecosystems and Macroinvertebrates**

Criteria	✓ Met	✗ Not Met	Observations
Accurate understanding of aquatic ecosystems			
Accurate understanding of macroinvertebrates			
Clear relationship between concepts			
Organized and visually clear diagram			

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2. **Concept Mapping: Visual Representation of Understanding**

Criteria	✓ Met	✗ Not Met	Observations
Accurate and relevant concepts included			
Clear and logical connections between concepts			
Depth of understanding demonstrated			
Organized and visually appealing map			

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3. **Discussion Prompt and Feedback Opportunity**

Criteria	✓ Met	✗ Not Met	Observations
Active participation in discussion			
Constructive feedback provided			
Engaged with peers and ideas			
Respectful and professional behavior			

This simple checkmark rubric allows for quick and clear assessment of key areas without needing detailed comments. You can easily track whether students meet expectations (✓) or need improvement (✗) in each area.

Macroinvertebrates-Based Learning Interventions Student Guide and Worksheets

Created by: Dr. Yajaira Torres (2024)

ACTIVITY #1 : MACRO DOTS DETECTIVES!

BACKGROUND: CALLING ALL CITIZEN SCIENTISTS!

Today, we become Macro Dots Detectives, using colorful clues to crack the case of water quality. Buckle up, because we're about to dive into the fascinating world of macroinvertebrates! Let's know a little bit about macroinvertebrates first.

What are Macroinvertebrates?

Macroinvertebrates are aquatic organisms that lack a backbone, that some can be seen without a microscope, and play a crucial role in freshwater ecosystems. They are essential components of the food web and serve as indicators of water quality and biodiversity. As primary food sources for fish, amphibians, and birds, macroinvertebrates support the overall biodiversity of aquatic ecosystems. They also contribute to nutrient cycling by breaking down organic matter and releasing nutrients into the water, which can be utilized by other organisms. Additionally, some macroinvertebrates can modify their habitats by creating shelters or altering the physical structure of the streambed.

Macroinvertebrates can be classified into different functional feeding groups, including shredders, grazers, collectors, and predators. Each group has its own unique role in the ecosystem, contributing to the overall balance and stability:

e. shredders - break down coarse organic matter
f. grazers - feed on algae and other fine particulate matter
g. collectors - gather organic matter from the streambed or water column
h. predators - feed on other macroinvertebrates or small fish

The diversity and abundance of macroinvertebrates can be used as bioindicators to assess the health of a stream or river. They are sensitive to changes in water quality, such as pollution, habitat degradation, and disturbance. By monitoring the presence or absence of specific macroinvertebrate species, scientists can identify sources of pollution and assess the extent of environmental damage.

GLOSSARY:

1. **Macroinvertebrates:** Small aquatic animals without backbones, such as insects, crustaceans, and worms.

2. **Pollution Sensitivity:** The ability of a macroinvertebrate to tolerate pollution in its environment.
3. **Key Guide:** A reference tool used to identify different species of macroinvertebrates.

OBJECTIVES:

- To identify common macroinvertebrate species found in local streams.
- To understand the concept of pollution sensitivity in macroinvertebrates.
- To assess the water quality of a local stream based on the presence or absence of certain macroinvertebrates.
- To develop critical thinking and observation skills.

PROCEDURE:

4. **Gather Your Gear:** Grab your magnifying glass (optional), tweezers (optional), collecting containers, and the printed Macroinvertebrate Key Guide.
5. **Head to the Stream:** Find a clean, shallow area in a local stream with good water flow. Remember to be respectful of the environment, always under the supervision of an adult and only collect a small number of macroinvertebrates for observation.
6. **Catch Some Critters:** Carefully scoop up a sample of the stream. Don't forget to grab leaves, branches, remove rocks, collect from the bottom too. Fill up the container with a small amount of stream water.
7. **Identify Your Detectives:** Use the Macroinvertebrate Key Guide (printed copy) to identify the different types of macroinvertebrates you collected. Match their physical characteristics to the pictures and descriptions in the guide.

Important Note: If you cannot collect samples from a stream, the teacher will provide some samples.

8. **Crack the Color Code:** Now for the detective work! Refer to the key below to understand what each color dot represents:

- **Green Dot:** This macroinvertebrate is **not very sensitive** to pollution. They can tolerate some level of contamination.
- **Yellow Dot:** This macroinvertebrate is **somewhat pollution tolerant**. They can survive in mildly polluted water but may struggle in highly polluted environments.
- **Red Dot:** This macroinvertebrate is **very sensitive** to pollution. Their presence indicates clean, healthy water.

9. **Dot Your Detectives:** Carefully place the corresponding-colored dots on each macroinvertebrate (the ones that you collected, and the others in the printed diagram) based on its pollution sensitivity level (according to the key).
10. **Analyze the Evidence:** Look at the collection of macroinvertebrates you've classified. Are there mostly green, yellow, or red dots?
    - **Mostly Green Dots:** The stream might have some level of pollution, but it's likely not a severe issue.
    - **Mostly Yellow Dots:** The water quality might be slightly compromised.
    - **Mostly Red Dots:** Congratulations! You've found a healthy stream with clean water!

Remember: This is just a snapshot of the stream's health at a specific location and time. By repeating this activity in different areas or over time, scientists and citizen scientists like you can gather valuable data to monitor water quality and protect our precious freshwater ecosystems.

Bonus Challenge: Share your findings with your classmates or a local environmental organization! You might even inspire others to become Macro Dots Detectives and protect our waterways!

WORKSHEET(S): Printed Macroinvertebrate Key Guide in Legal Size Paper
https://mdc.mo.gov/sites/default/files/mo_nature/assets/files/Life%20In%20River%20MDC%20Edits.pdf

ACTIVITY # 2: WATER QUALITY TESTING I & II

BACKGROUND:

Water is a vital substance essential for all life on Earth. It covers approximately 71% of the planet's surface and is found in various forms, including oceans, rivers, lakes, groundwater, and ice. Water plays a crucial role in maintaining biodiversity by providing a habitat for countless species and supporting essential ecological processes. The quality of water significantly impacts the health of ecosystems and human communities. Clean water is essential for drinking, cooking, sanitation, agriculture, industry, and recreation. Pollutants can contaminate water sources, rendering them unsafe for use and harming aquatic life. Pollutants can change the quality of water in several ways. They can alter the pH level, introduce harmful chemicals, increase nutrient levels, and reduce oxygen levels. These changes can disrupt the delicate balance of aquatic ecosystems and pose risks to human health. Water pollution can be caused by various sources, including:

e. Agricultural runoff: Excess fertilizers, pesticides, and animal waste that drain into water bodies;
f. Industrial waste: Discharge of toxic chemicals and pollutants from factories and manufacturing plants;
g. Sewage: Untreated or improperly treated wastewater from homes and businesses,
h. Oil spills: Accidental release of oil into water bodies, causing significant harm to marine life.

It is essential to monitor and assess water quality to ensure its safety for consumption, recreation, and environmental protection. By understanding the factors that can affect water quality and taking appropriate measures to prevent pollution, we can protect this precious resource for future generations.

GLOSSARY:

1. **pH:** A measure of the acidity or alkalinity of a solution.
2. **pH range**: The range of pH values within which a substance is considered acidic, neutral, or alkaline.

3. **Ammonia**: A colorless gas with a strong odor. It can be a pollutant in water.
4. **Nitrite**: A compound containing nitrogen and oxygen. It can be a pollutant in water.
5. **Nitrate**: A compound containing nitrogen and oxygen. It can be a pollutant in water.
6. **Water quality**: The chemical, physical, and biological characteristics of water
7. **Temperature:** A measure of the average kinetic energy of particles in a substance.
8. **Total Dissolved Solids (TDS):** A measure of the number of dissolved substances in water.
9. **pH:** A measure of the acidity or alkalinity of a solution.
10. **Conductivity:** A measure of the ability of a solution to conduct an electric current.

OBJECTIVES:

- To understand the importance of water quality testing.
- To learn how to measure key water quality parameters using a kit: (pH, pH range, Ammonia, Nitrites, and Nitrates) and a multiparametric water quality sensor (the temperature, total dissolved solids, pH and conductivity).
- To analyze and compare water quality data from different sources.

PROCEDURE:

- **Safety First:** Ensure you are wearing a lab coat and safety glasses.
- **Set Up Your Testing Area:** Prepare your table based on the instructions provides by the teacher and indicated in the worksheet.
- **Conduct Tests and Record the Data:** Follow the instructions provided with the water quality testing kit to measure the specified parameters for both water samples. Record the results obtained in your worksheet.
- **Color the Tubes:** Color the test tubes according to the color chart provided with the kit. If you are working with the sensor, complete the table.
- **Analyze Data:** Compare the data from both water samples and analyze the differences and similarities in water quality parameters. Complete the worksheet based on your observations and data analysis.

WORKSHEET(S): Macroinvertebrates-Based Learning Intervention - Water Quality Testing I & II (Water Quality Test Kit and Multiparametric Sensor)

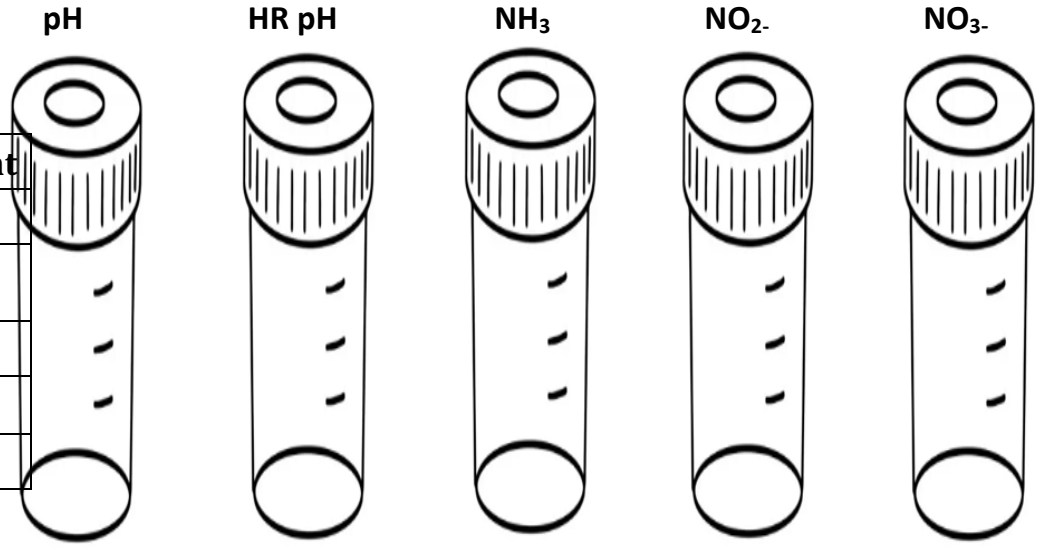
Name: _____ ____th Date: _____

Macroinvertebrates-Based Learning Intervention: Water Quality Testing I – Using a Kit Test

Instructions: Employ the water quality testing kit. Conduct measurements of the water samples for the specified parameters. Document the obtained results on the table below, color the tubes, and subsequently compare the data from both water samples.

Water Sample: _____

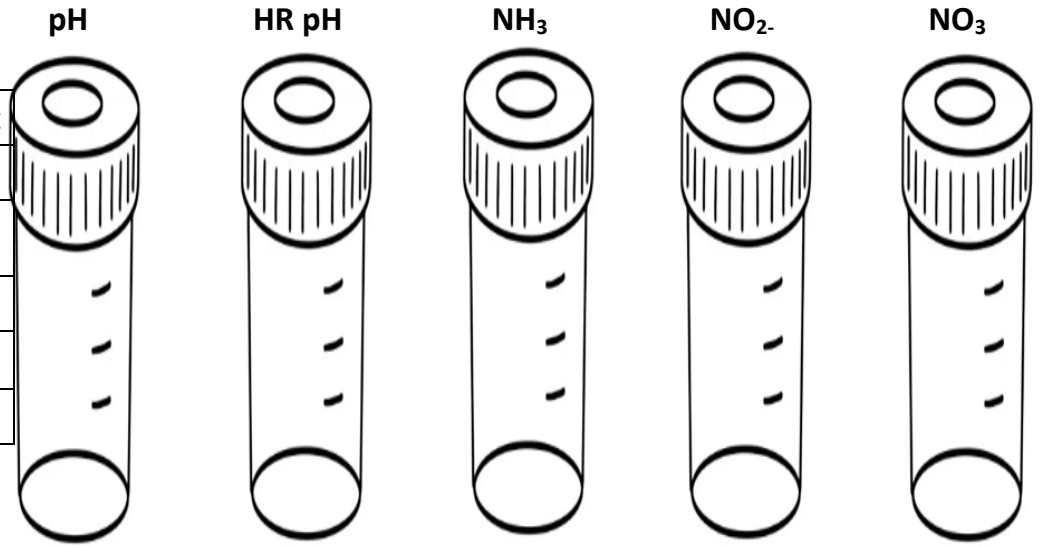
Parameter	Measurement
pH	
High Range pH	
Ammonia	
Nitrites	
Nitrates	



Conclusion:

Water Sample: _____

Parameter	Measurement
pH	
High Range pH	
Ammonia	
Nitrites	
Nitrates	



Conclusion:

Name: _____ ____th Date: _____

Macroinvertebrates-Based Learning Intervention: Water Quality Testing II - Using a Multi-Parameter Sensor

Instructions: Measure and analyze the temperature, total dissolved solids (TDS), pH, and conductivity of different water samples using a multi-parameter sensor.

Materials:

- Multi-parameter water quality sensor
- Beaker or clean container
- Water samples from different sources (e.g., tap water, bottled water, pond water, river water)
- Data table (provided on the side)
- Safety attire (lab coat, gloves, safety glasses)

Procedure:

5. **Calibration:**
   - Calibrate the multi-parameter sensor according to the manufacturer's instructions. This is crucial for accurate readings.
6. **Sample Collection:**
   - Collect water samples from the chosen sources and pour them into clean beakers or containers.
7. **Data Collection:**
   - Turn on the multi-parameter sensor.
   - Immerse the sensor probe into the first water sample.
   - Wait for the sensor to stabilize and record the readings for temperature, TDS, pH, and conductivity in the data table.
   - Repeat steps 3 and 4 for each water sample.
8. **Data Analysis:**
   - Compare the data collected for different water samples.
   - Analyze the differences in temperature, TDS, pH, and conductivity between the samples.
   - Discuss the potential implications of the results for water quality and use.

Sample Source / Place	Temperature (°C)	TDS (ppm)	pH	Conductivity (µS/cm)
Sample 1: _____				
Sample 2: _____				
Sample 3: _____				
Sample 4: _____				

Based on your data, what conclusions can you draw about the water quality of the different samples and the potential implications of the results?

ACTIVITIES #3, #4, #5, #6: EXPLORING MACROINVERTEBRATES WITH RESEARCH INTRO WORKSHEETS

In this phase of your lesson, you will dive into a set of Research Intro worksheets that will help you explore macroinvertebrates and their role in ecosystem health through hands-on activities and scientific investigation.

1. **Research Intro I: Decapoda in El Yunque Tropical Rain Forest (Activity #3)**
   Imagine you are exploring the lush streams of El Yunque, a tropical rainforest in Puerto Rico. In this activity, you will identify different shrimp species by their scientific names and learn about their roles in the ecosystem. Are they filter feeders, scavengers, or predators? You will also understand their classification and the important functions they serve in the stream environment.

2. **Research Intro II: Morphometric and Weight in Shrimps (Activity #4)**
   Here, you will measure the size and weight of shrimp using tools like calipers and a spring scale. By recording the length, width, and weight of each shrimp, you'll learn how scientists collect precise data and why this information is crucial for studying the health of aquatic organisms.

3. **Research Intro III: Macroinvertebrate Safari (Activity #5)**
   In this exciting activity, you will collect macroinvertebrates from a local water body. After identifying and classifying these small aquatic creatures, you'll use your observations to assess the water quality. This will help you understand how the diversity of macroinvertebrates can indicate the health of an ecosystem.

4. **Research Intro IV: Tracking the Effect of Emergent Disruptors (Activity #6)**
   In this activity, you will investigate how over-the-counter (OTC) analgesics affect shrimp behavior. By observing how these pollutants disrupt aquatic ecosystems, you will learn about the impacts of chemical contaminants on water quality and the health of aquatic life.

IMPORTANT: Your teacher will choose one of these activities to start with, giving you a focused exploration of a specific topic. Alternatively, you may work through all four activities, which will give you a more comprehensive understanding of macroinvertebrates and their role in maintaining ecosystem health. Each activity is designed to help you develop your scientific inquiry skills and critical thinking.

ACTIVITY #3: RESEARCH INTRO I
DECAPODA IN EL YUNQUE TROPICAL RAIN FOREST

BACKGROUND:

El Yunque Tropical Rainforest is one of the most diverse and unique ecosystems in Puerto Rico. It is home to a wide variety of plant and animal species, including many types of shrimp, known as Decapoda. Decapods are a group of crustaceans that include shrimp, crabs, lobsters, and crayfish. In the streams of El Yunque, these shrimps play crucial roles in maintaining the health of the aquatic ecosystem. They can be found hiding under rocks or leaves, where they feed on organic matter and contribute to nutrient cycling. Decapods in El Yunque are not only fascinating because of their diversity but also due to their ecological roles. Some are filter feeders, which help clean the water by removing small particles. Others are scavengers, breaking down dead organic material, while some are predators, hunting smaller organisms. Understanding the different species and their roles helps scientists monitor ecosystem health and biodiversity.

GLOSSARY:

- **Decapoda:** A class of crustaceans that includes shrimp, crabs, lobsters, and crayfish.
- **Filter Feeders:** Organisms that obtain their food by filtering small particles from the water.
- **Scavengers:** Organisms that feed on dead or decaying organic matter.
- **Predators:** Organisms that hunt and consume other animals.

OBJECTIVES:

- Identify different species of Decapoda found in El Yunque.
- Classify these shrimps based on their ecological roles (filter feeders, scavengers, or predators).
- Understand the importance of each species in maintaining the health of the stream ecosystem.

PROCEDURE:

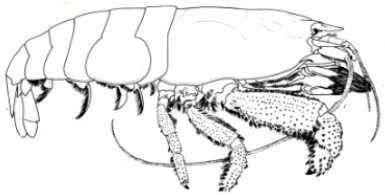
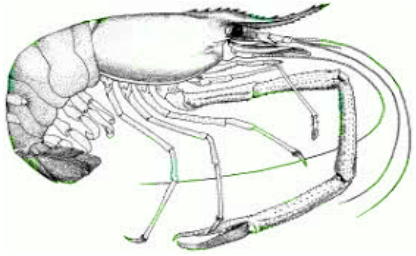
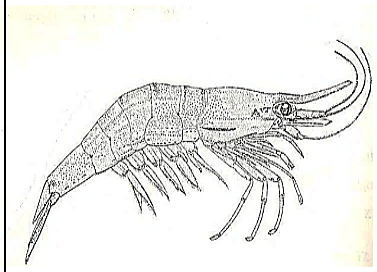
6. **Review Materials:** You will be provided with identification guides and images/specimens of shrimp from El Yunque.
7. **Group Work:** In small groups, examine the identification guides and images/specimens to identify different shrimp species.
8. **Classification:** Determine whether each shrimp is a filter feeder, scavenger, or predator based on its physical characteristics and behavior.
9. **Record Data:** Use the worksheet to document the scientific names, classifications, and roles of each identified species.
10. **Discuss Findings:** Share your findings with the class and discuss the roles of different shrimp in the ecosystem.

WORKSHEET: Macroinvertebrates-Based Learning Intervention: Research Intro I
What you know about the Decapoda in El Yunque Tropical Rain Forest?

Name: _____ ____th **Date:** _____

Macroinvertebrates-Based Learning Intervention: Research Intro I
What you know about the Decapoda in El Yunque Tropical Rain Forest?

Instructions: Imagine yourself exploring the lush, green depths of El Yunque Tropical Rainforest. As you wade through the crystal-clear streams, keep your eyes peeled for tiny, fascinating creatures hiding beneath the rocks and leaves. These are the shrimp of El Yunque! Can you identify them by their scientific names? Are they filter feeders, scavengers, or predators? And what secrets do they hold?

	Scientific name	Classification	3 Roles in the stream
			
			
			

ACTIVITY #4: RESEARCH INTRO II
MORPHOMETRIC AND WEIGHT IN SHRIMPS

BACKGROUND: Morphometrics is the study of the size and shape of organisms and their features. In scientific research, measuring the morphometric characteristics and weight of shrimp can provide valuable insights into their health, growth, and ecological role. Shrimps are important indicators of water quality and ecosystem health, and accurate measurements are essential for understanding their biology and the impacts of environmental changes. In this activity, you will use calipers to measure the length and width of shrimp and a spring scale to determine their weight. These measurements can help scientists assess the condition of the shrimp population and make inferences about the overall health of their habitat. By comparing measurements across different shrimp, you can also study variations within a population and understand how different factors might affect shrimp growth.

GLOSSARY:

- **Morphometrics:** The measurement of the size and shape of organisms and their features.
- **Calipers:** A tool used to measure the distance between two opposite sides of an object.
- **Spring Scale:** A device used to measure weight or force based on the extension of a spring.

OBJECTIVES:

- Measure the length, width, and weight of shrimp using appropriate tools.
- Understand the importance of these measurements in scientific research.
- Analyze the data to infer the health and growth of shrimp.

PROCEDURE:

5. **Review Materials:** You will use calipers, ziplock bags, and a spring scale for this activity.

6. **Measure Shrimp:** Use calipers to measure the length and width of each shrimp. Record these measurements in the worksheet.
7. **Weigh Shrimp:** Place the shrimp in a ziplock bag and use the spring scale to measure its weight. Record this weight in the worksheet.
8. **Analyze Data:** Compare the measurements of different shrimp and discuss any patterns or variations observed.

WORKSHEET: Macroinvertebrates-Based Learning Intervention: Research Intro II

Morphometric and Weight in Shrimps

Name: _____ ____th **Date:** _____

Macroinvertebrates-Based Learning Intervention: Research Intro II

Morphometric and Weight in Shrimps

Materials:

- Caliper
- Spring balance
- Hook
- Ziplock bag
- Shrimp
- Safety attire

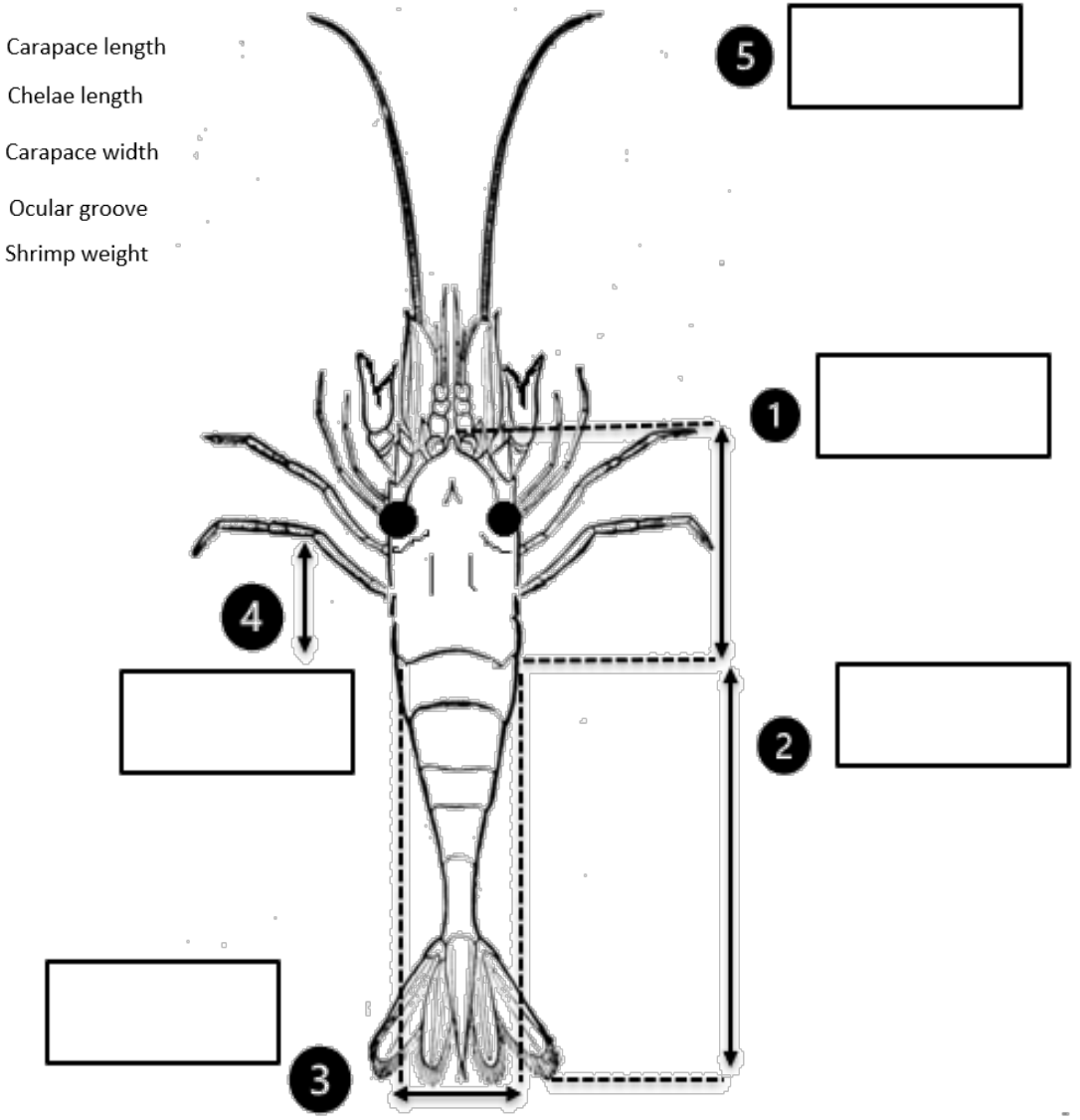
Instructions:

5. **Measure length and width:** Carefully grab the shrimp and with the caliper measure (in millimeters) each part. Write your measurements.

6. **Measure weight:** Attach the hook to the spring balance and the plastic bag to the hook. Weight the bag. Place the shrimp inside the bag. Read the weight measurement, subtract the bag measurement, and record it in grams.

7. **Calculate morphometric indices:** Calculate the length-to-width ratio by dividing the lengths by the width. Calculate the weight-to-length ratio by dividing the weight by the lengths.

8. **Analyze data:** Compare the morphometric measurements of your shrimp with the other tables. In your notebook, create a table and a graph with the data of all shrimps' measures.



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ACTIVITY #5: RESEARCH INTRO III
MACROINVERTEBRATE SAFARI

BACKGROUND:

Macroinvertebrates are small, aquatic animals without a backbone that are visible to the naked eye. They play crucial roles in freshwater ecosystems, acting as indicators of water quality and contributing to nutrient cycling and food webs. By studying macroinvertebrates, scientists can assess the health of aquatic environments and detect changes due to pollution or habitat alteration. In this activity, you will collect, identify, and classify macroinvertebrates from a local water body. You will use their presence and diversity to assess water quality. A healthy water body typically supports a diverse community of macroinvertebrates, while pollution or other environmental stressors can reduce this diversity.

GLOSSARY:

1. **Macroinvertebrates:** Small, aquatic animals without a backbone, visible to the naked eye.
2. **Bioindicators:** Organisms used to assess environmental conditions or changes.
3. **Diversity:** The variety of different species present in an ecosystem.

OBJECTIVES:

- Collect macroinvertebrates from a local water body.
- Identify and classify the collected macroinvertebrates.
- Assess water quality based on the diversity and types of macroinvertebrates found.

PROCEDURE:

5. Field Collection: Use collection nets and sorting trays to gather macroinvertebrates from the water body.
6. Identification: Examine the collected specimens using identification guides and magnifying glasses.

7. Classification: Classify the macroinvertebrates based on their species and role in the ecosystem.
8. Assess Water Quality: Use the diversity and abundance of macroinvertebrates to evaluate the water quality and discuss your findings.

WORKSHEET: Macroinvertebrates-Based Learning Interventions: Research Intro III
Macroinvertebrate Safari
(Collection, Identification, and Classification of Macroinvertebrates)

Name: _____ ____th **Date:** _____

Macroinvertebrates-Based Learning Interventions: Research Intro III
Macroinvertebrate Safari
(Collection, Identification, and Classification of Macroinvertebrates)

Objective: Students will collect, identify, and classify macroinvertebrates from a local water body, using their observations to assess the water quality.

Materials

1. **Trays**
2. **Bucket**
3. **Scissors**
4. **Tweezers**
5. **Data sheets**
6. **Micro pipets**
7. **Microscopes**
8. **Magnifying glasses**
9. **Identification guides**
10. **Nets of different mesh sizes**
11. **Water bottles**
12. **Ethylic Alcohol**
13. **Waterproof marker (MICRON-Black), acid paper and glass sampling containers**
14. **Protective attire (In classroom: lab coat, gloves and safety glasses)**
15. **Safety waders and gloves (optional – for sampling on water bodies)**

Procedure

For sampling in the water body (On Site):

1. **Safety First:** Discuss safety precautions with students, such as wearing appropriate footwear, avoiding areas with strong currents, and being aware of potential hazards.
2. **Choose a Location:** Select a nearby stream, pond, or river. Ensure that it is a safe and accessible location.
3. **Collect Samples:**
   a. Use nets of different mesh sizes to collect macroinvertebrates from various habitats within the water body (e.g., bottom sediments, vegetation, water column).
   b. Transfer the collected organisms to the bucket filled with water.

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In the classroom:

4. **Identification and Classification:**

- Divide the sample collected in the trays.
- Use the water bottle to wash and remove the leaves, rocks, and pieces of woods from the tray.
- Using magnifying glasses and identification guides, students will group the macroinvertebrates.
- With the tweezers and/or the micro pipet, group the macroinvertebrates based on their physical characteristics and taxonomic classification.
- Use the microscope to assure your classification and to identify smaller organisms.
- Identify the macroinvertebrates they have collected.
- Cut small rectangles of the acid paper.
  ID Key to write on the paper: Date/Place/ Person / Macro ID
- Place the ID key inside the glass sampling containers, with the macroinvertebrates of the same group.
- Fill the glass containers with the ethylic alcohol.
- Record the findings on the data sheets, including the number of individuals, species identified, and any noticeable characteristics.
- Use the data to assess the overall health of the water body.

5. Data Analysis:

- Discuss the types of macroinvertebrates found.
- Create a class chart or graph to visualize the results.
- Take the bucket to the classroom.

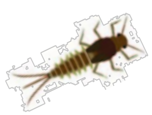
Name: ____ ____th Date: ____

Macroinvertebrates-Based Learning Interventions

Macroinvertebrate Safari - Data Sheet

Sample Location:	Date:	Time:		
Macroinvertebrate [Species]	**Quantity [Number]**	**Tolerance to Pollution**		
		Sensitive	**Somewhat sensitive**	**Tolerant**
		Number of checkmarks: ___ times 3 = ___	Number of checkmarks: ___ times 2 = ___	Number of checkmarks: ___ times 1 = ___

Add sensitive ____ + somewhat sensitive ____ + tolerant ____ = ____ Water Quality Rating



Water Quality Rating (check one)

____ Excellent (>22) ____ Good (17 – 22) ____ Fair (11 – 16) ____ Poor (<11)

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ACTIVITY # 6: RESEARCH INTRO IV - TRACKING THE EFFECT OF EMERGENT DISRUPTORS (Optional – For Students interested in Research and / or Science Fair)

BACKGROUND:

Emergent disruptors are substances that enter aquatic ecosystems and can impact the health of aquatic organisms. Over the counter (OTC) analgesics, such as acetaminophen, are examples of these disruptors. When these chemicals are present in water bodies, they can affect the behavior and health of aquatic organisms, including shrimp. Studying these effects helps scientists understand the broader impacts of pollution on ecosystems. In this activity, you will observe how different concentrations of OTC analgesics affect shrimp behavior. By tracking these changes, you will learn about the potential risks posed by pollutants and the importance of monitoring and managing chemical contaminants in aquatic environments.

GLOSSARY:

1. **Emergent Disruptors:** Substances that disrupt the normal function of ecosystems when they enter the environment.
2. **Analgesics:** Medications used to relieve pain, which can sometimes enter water bodies through wastewater.
3. **Behavioral Changes**: Alterations in the actions or responses of organisms due to external factors.

OBJECTIVES:

- Observe and record the behavior of shrimp exposed to different concentrations of OTC analgesics.
- Analyze how these substances impact shrimp health and behavior.
- Understand the implications of chemical pollutants on aquatic ecosystems.

PROCEDURE:

12. Construct the dark Recording Station (PVC stands, cameras, light mat, red acrylic box, black curtains and timer)
13. Identify the Tanks: Label the tanks as "Control" and "Experimental."
14. Prepare Water: Fill each tank with three cups of water.
15. Set Up Oxygenation: Install and set up the oxygenation devices in each tank.
16. Measure Water Quality (Control): Measure and record the water quality parameters (e.g., pH, temperature, dissolved oxygen) for the control tank.
17. Prepare Analgesic Solution: Weigh the amount of OTC analgesic using the weighting plate and weight machine.
18. Add Analgesic: Add the measured OTC analgesic to the experimental tanks.
19. Place Shrimp: Introduce shrimp into the tanks with water containing different concentrations of OTC analgesics.
20. Observation: Monitor and record the behavior of the shrimp over time (5 minutes with a mini camera in the dark station), noting any changes or abnormal behaviors.
21. Recording Data: Use the worksheet to document your observations and any patterns in behavior.
22. Discussion: Discuss your findings with the class and consider the broader implications for water quality and ecosystem health.

WORKSHEET: Research Intro IV

Lolli Tracking the Effect of Emergent Stressors in Fresh Water

- Concentration of OTC Analgesic
- Behavior Observed (e.g., inactivity, unusual swimming patterns)
- Implications for Water Quality

Name: _____ ____th **Date:** _____

Macroinvertebrates-Based Learning Intervention: Research Intro IV

Lolli Tracking the Effect of Emergent Stressors in Fresh Water

Objective: To investigate how different concentrations of over-the-counter (OTC) analgesics affect the behavior of shrimp in freshwater. You will compare shrimp behavior in experimental tanks with varying levels of analgesics and observe any changes through video recordings.

Part 1: Setup

1. Tank Identification	**Control Tank: Yes / No** **Experimental Tank 1: Yes / No** **Experimental Tank 2: Yes / No**
2. Water Preparation	**Amount of Water in Each Tank: 3 cups in each tank** **Yes / No**
3. Oxygenation Devices	**Device Setup Completed in each tank** **Yes / No**

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4. Water Quality Measurement **Control Tank Measurements:** **a. pH: _____** **b. Temperature (°C): _____** **c. Dissolved Oxygen (mg/L): _____** **d. Conductivity (µS/cm): _____**	**Experimental Tank 1 Measurements (with the OTC)** **a. pH: _____** **b. Temperature (°C): _____** **c. Dissolved Oxygen (mg/L): _____** **d. Conductivity (µS/cm): _____** **Experimental Tank 2 Measurements (with the OTC)** **a. pH: _____** **b. Temperature (°C): _____** **c. Dissolved Oxygen (mg/L): _____** **d. Conductivity (µS/cm): _____**
5. Analgesic Preparation	**Analgesic Type: OTC Analgesic _____** **Concentration of OTC Analgesic** **a. Control Tank: 0 g/L** **b. Experimental Tank 1: _____ g/L** **c. Experimental Tank 2: _____ g/L**
6. Behavioral Observation	**Video Recording Started: Yes / No** **Observation Period: _____ minutes**

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Part 2: Observations

1. **Behavior Observed (Based on Video Recordings):**
    a. **Control Tank:**
        - **Normal Behavior: Yes / No**
        - **Abnormal Behavior: Yes / No**
        - **Description of Behavior: _____**
    b. **Experimental Tank 1:**
        - **Normal Behavior: Yes / No**
        - **Abnormal Behavior: Yes / No**
        - **Description of Behavior: _____**
    c. **Experimental Tank 2:**
        - **Normal Behavior: Yes / No**
        - **Abnormal Behavior: Yes / No**
        - **Description of Behavior: _____**

Part 3: Analysis

4. **Comparative Analysis: Describe any differences in shrimp behavior between the control tank and the experimental tanks:**

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5. **Implications for Water Quality: Based on your observations, how might the presence of OTC analgesics affect water quality and the health of aquatic ecosystems?**

6. **Implications for the Macroinvertebrate: Based on your results, is there any death rate during your experimental process?**

Reflection:

- **What did you learn about the impact of OTC analgesics on shrimp behavior?**

- **How could this experiment be improved or extended in future studies?**

Last Question: Ecological Awareness Check

Please check all that apply to indicate the elements of ecological awareness you gained from this activity:

Item	No	Yes
I recognize how human-made chemicals (like OTC analgesics) can affect aquatic ecosystems.		
I understand the importance of water quality parameters (pH, temperature, dissolved oxygen, conductivity) in the health of aquatic life.		
I can identify the role of macroinvertebrates as bioindicators of water quality.		
I learned that even low concentrations of pollutants can have significant effects on organisms.		
I have a deeper appreciation for how human activities impact freshwater ecosystems.		
I understand the need for responsible disposal and regulation of pharmaceuticals to protect water quality.		
I recognize the potential cumulative effects of environmental stressors on aquatic species.		
I learned that experimental design and behavioral observations can help assess environmental impacts.		

Teacher's Comments:

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Pre and Post Test

Aquatic Ecology and Research Competencies Assessment

Introduction: This test assesses your understanding of research competencies, macroinvertebrate identification, water quality testing, the three shrimps in El Yunque, macroinvertebrates as bioindicators, and the impact of emerging stressors (OTC analgesics) on aquatic environments.

Instructions: Carefully read the instructions for each part and answer the questions accordingly. Circle the right answer from the options (a, b, c, or d) for each question.

Do your best, and good luck!

Part A: Research Competences (5 items)

1. What is a hypothesis in scientific research?
   a. a conclusion drawn from data
   b. an educated guess predicting the outcome
   c. a method for data collection
   d. a variable in the experiment

2. Which is usually the first step in the scientific method?
   a. data analysis
   b. hypothesis formulation
   c. observation and question
   d. experimentation

3. In research, control variables are used to:
   a. ensure the accuracy of the hypothesis.
   b. test the effects of independent variables.
   c. keep other variables constant.
   d. make experiments faster.

4. Which tool would best help in organizing research data?
   a. a barometer
   b. a spreadsheet
   c. a microscope
   d. a caliper

5. The dependent variable in an experiment is:
   a. the factor that remains unchanged.
   b. the factor that is measured or observed.
   c. a constant factor.
   d. a hypothesis.

Part B: Identification and Classification of Macroinvertebrates (5 items)

6. Which of the following is a pollution-sensitive macroinvertebrate?
   a. *mayfly* nymph
   b. mosquito larvae
   c. leech
   d. snail

7. Macroinvertebrates are classified by:
   a. their primary food source
   b. tolerance to pollution.
   c. taxonomy and physical characteristics.
   d. All the options above.

8. Which of the following is an example of a benthic macroinvertebrate?
   a. water strider
   b. dragonfly
   c. *caddisfly* larvae
   d. grasshopper

9. Macroinvertebrates that shred organic matter into smaller pieces are called:
   a. collectors.
   b. predators.
   c. shredders.
   d. scrapers.

10. In which type of habitat are most macroinvertebrates found?
   a. desert
   b. aquatic environments
   c. grasslands
   d. mountains

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Part C: Water Quality Testing (5 items)

11. The pH of a healthy freshwater stream should be within which range?
   a. 1-3
   b. 4-6
   c. 6.5-8.5
   d. 10-12

12. What tool is used to measure the Total Dissolved Solids (TDS) in water?
   a. thermometer
   b. conductivity meter
   c. pH meter
   d. barometer

13. Which of these factors directly affects dissolved oxygen levels in water?
   a. temperature
   b. pH
   c. TDS
   d. Water color

14. What does TDS measure in a water sample?
   a. the concentration of dissolved salts and minerals
   b. the level of dissolved oxygen
   c. the organic content in water
   d. water hardness

15. Which of the following affects water temperature in a stream?
   a. amount of sunlight
   b. presence of fish
   c. depth of the water
   d. air pressure

Part D: The Three Shrimps in El Yunque (5 items)

16. Which genus of shrimp in El Yunque is known for filter-feeding?
   a. Atya
   b. Xiphocaris
   c. Macrobrachium
   d. Both *Atya* and *Xiphocaris*

17. *Xiphocaris* shrimps are typically found in which part of the river?
   a. deep ocean areas
   b. shallow stream areas
   c. high-altitude streams
   d. lowland lakes

18. *Macrobrachium* shrimps are distinguished by their:
   a. small size and filter-feeding behavior.
   b. large claws and aggressive behavior.
   c. ability to tolerate polluted waters.
   d. bright coloration.

19. *Atya* shrimp primarily feed by:
   a. grazing on algae.
   b. filtering particles from the water.
   c. hunting small fish.
   d. consuming detritus.

20. Which of the following is NOT true about *Macrobrachium* shrimp?
   a. They are typically smaller than *Atya* shrimp.
   b. They have large pincers.
   c. They play an important role in the detritus cycle.
   d. They are found in both freshwater and saltwater environments.

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Part E: Macroinvertebrates as Bioindicators (5 items)

21. Macroinvertebrates are effective bioindicators because:
   a. they can survive in all types of environments.
   b. their diversity reflects the water quality.
   c. they are the largest organisms in aquatic ecosystems.
   d. they are easy to see with the naked eye.

22. Which macroinvertebrate group is typically found in polluted waters?
   a. Stoneflies
   b. Caddisflies
   c. Mayflies
   d. Leeches

23. Why are pollution-sensitive macroinvertebrates important in assessing water quality?
   a. They indicate high biodiversity.
   b. They can only live in unpolluted water.
   c. They consume pollutants.
   d. They reproduce quickly in contaminated environments.

24. Macroinvertebrates that thrive in polluted environments are called:
   a. collectors
   b. pollution-tolerant species
   c. biofilters
   d. sensitive species

25. The presence of diverse macroinvertebrate species in a water body indicates:
   a. poor water quality.
   b. high levels of pollution.
   c. healthy and stable water conditions.
   d. high temperature levels.

Part F: Emerging Stressors (OTC Analgesics) Affecting Aquatic Environments (5 items)

26. OTC analgesics like ibuprofen enter aquatic environments primarily through:
   a. agricultural runoff.
   b. improper disposal of medications.
   c. industrial waste.
   d. animal migration.

27. One of the main effects of OTC analgesics on aquatic organisms is:
   a. changes in reproductive behavior.
   b. enhanced growth.
   c. increased oxygen production.
   d. no significant impact.

28. Why are OTC analgesics considered emerging stressors in aquatic environments?
   a. They are rapidly broken down by sunlight.
   b. They improve water quality.
   c. They are beneficial for aquatic life.
   d. They accumulate and persist in water bodies.

29. The primary method for detecting OTC analgesics in water involves:
   a. microscopy.
   b. DNA sequencing.
   c. chemical analysis.
   d. measuring water temperature.

30. How do OTC analgesics affect macroinvertebrates like shrimp?
   a. They help them filter more particles.
   b. They alter their behavior and stress levels.
   c. They have no effect.
   d. They improve their immune system.

Part G: Macroinvertebrates' Use in Water Quality and Ecological Awareness (3 Items)

31. How do macroinvertebrates serve as bioindicators of water quality?

a. Their presence, absence, or abundance can provide insights into the physical and chemical conditions of the water.
b. They are not useful for monitoring water quality because they only exist in certain regions.
c. Macroinvertebrates can only indicate water temperature, but not other water quality factors.
d. Only certain species of macroinvertebrates are useful for determining human impact on ecosystems.

32. Why is ecological awareness of macroinvertebrates important for the health of freshwater ecosystems?

a. Macroinvertebrates are the primary producers in aquatic food chains, making them crucial for ecosystem function.
b. Macroinvertebrates are resilient to environmental changes, so they are not significant for ecological monitoring.
c. Their presence guarantees high biodiversity in aquatic ecosystems, irrespective of other factors.
d. They act as indicators of pollution and are essential for assessing the ecological balance of freshwater environments.

33. Which of the following best describes how understanding the role of macroinvertebrates in water quality can contribute to ecological awareness?

a. It helps scientists focus only on large species of aquatic organisms, ignoring smaller organisms like macroinvertebrates.
b. By studying macroinvertebrates, we gain a better understanding of how pollutants affect ecosystems and how we can mitigate their impact.
c. Ecological awareness focuses primarily on the appearance of macroinvertebrates, without considering their behavior or habitat needs.
d. It is unnecessary to study macroinvertebrates because they do not have significant ecological roles in aquatic ecosystems.

Part H: Macroinvertebrates Data Analysis (3 Items)

Macroinvertebrate Abundance Data

Species	Control Tank (Abundance)	Experimental Tank 1 (Abundance)	Experimental Tank 2 (Abundance)	Pollution Tolerance
Mayfly Larvae	25	12	8	Sensitive
Midge Larvae	5	18	30	Pollution-Tolerant
Caddisfly Larvae	20	18	15	Sensitive
Leeches	3	5	8	Pollution-Tolerant
Dragonfly Nymphs	12	6	4	Moderately Sensitive

34. The decrease in the abundance of Mayfly Larvae from the Control Tank to both Experimental Tanks suggests that pollution may be negatively affecting sensitive species in the experimental tanks.

a. True
b. False

35. The increase in Midge Larvae abundance in both Experimental Tanks indicates that the water quality has improved, as Midge Larvae are considered pollution-sensitive species.

a. True
b. False

36. The decrease in the abundance of Dragonfly Nymphs in the experimental tanks suggests that the water quality may be affecting moderately sensitive species, as seen by the reduction from 12 in the Control Tank to 6 and 4 in the experimental tanks.

a. True
b. False

Test Name: Aquatic Ecology and Research Competencies Assessment
Answer Key

Part A: Research Competences

1. B
2. C
3. C
4. B
5. B

Part B: Identification and Classification of Macroinvertebrates

6. A
7. D
8. C
9. C
10. B

Part C: Water Quality Testing (pH, temperature, TDS)

11. C
12. B
13. A
14. A
15. A

Part D: The 3 Shrimps in El Yunque (*Atya, Xiphocaris, Macrobrachium)*

16. A
17. B
18. B
19. B
20. A

Part E: Macroinvertebrates as Bioindicators

21. B
22. D
23. B
24. B
25. C

Part F: Emerging Stressors (OTC Analgesics) Affecting Aquatic Environments

26. B
27. A
28. D
29. C
30. B

Part G: Macroinvertebrates' Use in Water Quality and Ecological Awareness (3 Items)

31. A
32. D
33. B

Part H: Macroinvertebrates Data Analysis (3 Items)

34. T
35. F
36. T

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