**Scientific Method: Background Information**

**& Pre and Post Activities**

**BACKGROUND INFORMATION**

**BASIC ECOLOGICAL CONCEPTS**

Ecology is the study of the relationships between organisms and their environments. An ecologist asks questions like: Where does this organism live and what characteristics make it particularly suited for that location? How does this organism get its food? What other organisms eat it? By asking questions such as these some basic principles have emerged. Understanding the following basic ecological concepts help us appreciate the complexity of life residing in and around the Bay.

Everything is related to everything else

Perhaps the easiest place to see interdependence in the environment is to look at food. All food on this planet is essentially made by plants through the process of *photosynthesis. Herbivores* are animals, which depend directly on plants for food. *Carnivores* eat herbivores. Take away all of the plants and there would be no animals. Can a plant, then, exist independently of all other organisms? No. Although it doesn't eat, a plant needs *nutrients* and is dependent on *decomposers* (bacteria and fungi) to break down dead organisms, thereby releasing these nutrients for use by the living plant.

Everything depends on something else

All organisms are also dependent on factors in the physical environment. They must have a source of water. Animals must have oxygen to breathe. Plants must have sunlight to perform photosynthesis. You can probably think of many more examples of how organisms are dependent on their environments.

Everything must go somewhere

No object ever disappears completely from the face of the earth. It may be broken down into atoms and be used to build something else, but those atoms are still there. In this way, nature deals with waste by recycling. Any plant or animal that does not become food for some animal becomes food for decomposers, which free the nutrients to be used again. Anything that cannot be decomposed must remain in the environment as it is. What are some examples of this kind of waste? The next time you throw something away, you might remember that there really is no "away" to throw it to.

Earth's resources are limited

How often do you run out of time to do what you want or need to do? Everyone knows that each day only has so much time in it, and that we have to be careful how we use it if we are going to accomplish everything we need to. The earth's available resources are like time in that we have to be careful how we use them, or they might run out. There is only so much gold, so much petroleum, so much fresh water, so much food, and so much space. All organisms are limited by the availability of resources, but humans have a special opportunity and a special responsibility. Although plants cannot make a decision to conserve clean water, humans can. To do this intelligently we must find out how much of each resource is available and then we must budget our use. We must also think about recycling. The earth can recycle its components naturally but humans must make special efforts to preserve the natural resources.

**SCIENTIFIC METHOD**

A Scientific Method Combination program is an opportunity for students to be marine scientists. They need to bring a scientific attitude, and know they are the researchers on this project, so the quality of science we conduct depends on their attentive and careful participation.

Throughout the program, students will be using the scientific method. The scientific method is a series of steps:

* OBSERVATION & INITIAL QUESTIONS: Make observations using all senses. What interesting questions can be asked? What doesn't seem to fit in the picture?
* HYPOTHESIS: A hypothesis is tentative explanation for a problem that can be tested with further investigation. A hypothesis can be made by doing research, asking other people for information, and reading other people's work about the subject.
* MATERIALS & METHODS: What methods should be used to answer a research question and obtain results? Think about the equipment needed to run the experiment.
* DATA & RESULTS: The next step is to run the experiment. It is important to understand that the hypothesis must be testable, meaning that information (or data) can be recorded from the experiment. The recorded data are considered the results of the experiment.
* CONCLUSION & DISCUSSION: Now is the time to answer the question “why?” Why did the experiment give these results? Do the results support the hypothesis? Why, or why not? In this section, discuss how the experiment could be improved. What were some scientific errors made during the experiment?

**GLOSSARY**

|  |  |
| --- | --- |
| **ADAPTATION** | Modification of an organism in order to survive within its habitat. |
| **ALGAE** | Primitive aquatic plants that lack true stems, roots and leaves. They are in their own kingdom. |
| **BEACH WRACK** | Seaweed that has washed ashore. |
| **BENTHOS** | The substrate at the bottom of a body of water; the adjectival form of benthos is benthic. |
| **BIODEGRADABLE** | Something capable of being broken down to simple compounds, especially into harmless products, by the action of microorganisms. |
| **BIODIVERSITY** | The richness, abundance and variety of life across all trophic levels of which all ecological systems, including the planet earth, are comprised. |
| **BIVALVE** | A Mollusk having two shell hinged together. e.g. clam, oyster and mussel. |
| **BRACKISH** | Water that has more salt than fresh water but not as much as seawater. |
| **BYSSAL THREAD** | Tough threads of protein secreted by a gland in the foot of the mussel and used to attach it to rocks, piers etc. |
| **CAMOUFLAGE** | Method of hiding in which organisms blend in with their surroundings. |
| **CARAPACE** | In crustaceans, a hard portion of the exoskeleton that covers the fused head and thorax. |
| **CARNIVORE** | An animal that consumes other living animals. |
| **COMMUNITY** | A group of plants or animals living in the same area and depending on one another for survival. |
| **CONSUMER** | An organism that gets its nutrients by eating other organisms. |
| **CRUSTACEAN** | An animal with a hard outside shell, antennae, mandibles and compound eyes. e.g. crabs, shrimps and barnacles. |
| **DECOMPOSER** | An organism that breaks down organic material and releases simple substances usable by other living things. Examples of decomposers are bacteria and fungi. |
| **DECOMPOSITION** | The breakdown of substances into inorganic forms. |
| **DEPOSIT FEEDER** | An animal that feeds by ingesting substrate and filtering out the small organic particles on the substrate. |
| **DETRITIVORE** | An animal that eats detritus. |
| **DETRITUS** | Dead plant and animal material. |
| **DIATOM** | A type of microscopic, one-celled photosynthetic organism. All diatoms are surrounded by a silica shell and most are a golden brown in color. |
| **DICHOTOMOUS KEY** | A tool used to identify organisms based on their physical features. |
| **DISSOLVED OXYGEN** | Oxygen that has dissolved in water and can be used for respiration. |
| **ECOLOGY** | The study of relationships between organisms and their environment. |
| **EDGE COMMUNITY** | A productive area where land and sea interface. This community, because of its proximity to land, receives huge inputs of sediment, nutrients and freshwater, which in turn supports a diversity of plants and animals. |
| **ENDANGERED** | An organism that is threatened with extinction. |
| **ENVIRONMENT** | The sum of all physical and biological factors that affect an organism. |
| **ESTUARY** | A semi-enclosed body of water where salt water and fresh water meet and mix. |
| **EXOSKELETON** | A hard encasement deposited on the surface of an animal, such as the outer covering of arthropods that provides protection from abrasion, predation, desiccation, etc. |
| **FILTER FEEDER** | An animal which extracts food particles by straining the water. Examples of filter feeders are clams, oysters, sponges and some fish. |
| **FOOD CHAIN** | A sequence of living organisms in an ecosystem in which members of one level feed on those in the level below and in turn are eaten by those in the level above them. |
| **FOOD WEB** | An assemblage of organisms in an ecosystem, including plants, herbivores and carnivores, which shows the relationship of "who eats whom." |
| **FOOT** | The wide, flat or wedge-shaped muscle of mollusks used for crawling, adhering and/or digging. |
| **GEOLOGY** | The study of the composition and structure of the earth. |
| **GILL** | An organ used for underwater breathing or respiration by fishes and some invertebrates. |
| **HABITAT** | The particular area in which an organism normally lives. |
| **HERBIVORE** | An animal that eats plants. |
| **HOLDFAST** | The root-like part of a seaweed that anchors it to the seafloor. |
| **ICHTHYOLOGY** | The study of fish. |
| **INVERTEBRATE** | An animal without a backbone. |
| **MANTLE** | An outer sheet of fleshy tissue (in mollusks) secreting the shell and forming the chamber to enclose the internal organs. |
| **MOLLUSK** | The second largest Phylum of animals. Mollusks have soft bodies, a foot, visceral mass, and a mantle. Most also have a shell made of calcium carbonate. Snails, clams, slugs, squid and octopus are examples of mollusks. |
| **MUDFLAT** | The salty soil area of land between the lowest low and highest low tide that is flooded with sea water daily and upon which very few plants grow. |
| **NEAP TIDES** | Low amplitude tides that occur during quarter moons, when the moon's pull is at a right angle in relation to the pull of the sun. |
| **NEKTON** | Swimming animals of open water, the adjectival form of nekton is nektonic. |
| **NEMATOCYST** | In cnidarians, stinging capsules used in defense and gathering food. |
| **NUTRIENTS** | The raw materials necessary for continuing life processes. |
| **OMNIVORE** | An organism that eats both plant and animal material. |
| **PHOTOSYNTHESIS** | The process used by plants to make food; in this process light energy is used to combine carbon dioxide and water to make carbohydrates (sugar and starch); oxygen gas is given off as a by-product. |
| **PHYTOPLANKTON** | Algae, usually microscopic, which freely drift in the sunlit portions of the water column. |
| **PLANKTON** | Drifting aquatic plants and animals; the adjectival form of plankton is planktonic, and a planktonic organism is called a plankter. |
| **POLLUTION** | Harmful impact on the environment resulting from human activities. |
| **PREDATOR** | An animal that captures other animals for food. |
| **PREY** | An animal caught for food. |
| **PRODUCER** | An organism that makes its own food; an example of a producer is a green plant. |
| **RESPIRATION** | Process used by animals and plants to release energy from food; this process requires oxygen and releases carbon dioxide and water. |
| **SALINITY** | The amount of salt in the water. Measured in parts per thousand. |
| **SALT MARSH** | Salt-water wetland between terrestrial and marine ecosystems; salt marshes can also be seasonal or tidal wetlands. |
| **SAND** | Sediment particle which can be distinguished with the naked eye; particle diameters range from 1/16 (.0625) mm. |
| **SCAVENGER** | An organism that is an opportunistic feeder; scavengers usually include dead and decaying animal flesh in their diets. |
| **SIPHONS** | The feeding tubes used by some bivalves (clams and oysters) to filter plankton. |
| **SPECIES** | A population of plants or animals that are able to produce viable of with each other and not with other species. |
| **SPRING TIDES** | Occurs every two weeks near the times of either the full or new moon. These are high amplitude tides that occur when the sun, moon, and the earth are lined up. |
| **STIPE** | The stem-like part of a kelp plant. |
| **SYMMETRY** | Correspondence in size, form, and arrangement of parts. |
| **TENTACLE** | A slender, flexible appendage. |
| **TIDES** | The daily rise and fall of the sea level along a shore, occurs twice a day on our local shores. |
| **TUBE FEET** | In echinoderms, hollow appendages filled with water and operated by the water-vascular system. Used for attachment, movement and the capture of water. |
| **UPLAND** | Ground that is elevated above the lowlands, marshlands, or rivers. |
| **VERTEBRATE** | An animal with a backbone. The back bone can be made of bone or of cartilage like in some fish (sharks and rays). |
| **WATER-VASCULAR** | A system of canals, bulbs and appendages filled with sea water. This system is involved in locomotion in echinoderms. |
| **WETLANDS** | Areas that periodically have waterlogged soils, support plants adapted to wet soil, and are covered or occasionally submerged by water. |
| **ZOOPLANKTON** | Animal plankton. |

**PRE-VISIT ACTIVITIES**

You may want to ask your librarian to set aside ecology or marine science books for your class, or ask students to bring books and magazines from home to share.

**SCIENTIFIC CLASSIFICATION**

Demonstrate the meaning of scientific classification by having students categorize inanimate objects according to their own framework. You could use fruit, or something ordinary such as different kinds of nails (wood, standard, aluminum, galvanized, ringed, headless), to each small group. Have them categorize and then share their results with each other to start a general discussion on classification. Do we need it? Is any one type of classification better than another? Is there a benefit to sticking to one standardized system of classification?

**ORGANISM REACTIONS**

A. Varying salinity

Have students make wet mounts of a thin section of red onion bulb. Mount in 1% NaCl (salt) solution and observe effects. Flush with fresh water and observe effects. Have students explain the reactions.

B. Varying temperature

Put equal numbers of fruit flies in jars and keep them at different temperatures for a few minutes. Observe relative activity rates. If a pond or other body of water is nearby, measure air and water temperatures at different times of the day to see which environment has more stable temperatures.

**Activities/Curriculum links:**

<http://aswc.seagrant.uaf.edu/kindergarten/investigation-1.html>

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| --- |
| <https://coast.noaa.gov/estuaries/curriculum/> |
| <http://www.waquoitbayreserve.org/research-monitoring/salt-marsh-carbon-project/teachers/> |
| <https://dataintheclassroom.noaa.gov/>   |  | | --- | | <http://www.noaa.gov/resource-collections/hands-on-science-activities> | | <https://coast.noaa.gov/estuaries/curriculum/human-impacts-on-estuaries-terrible-spill-in-grand-bay.html> | |
| <http://www.afterschoolalliance.org/STEM-curriculum.cfm> |
| <https://sc.club.northwestern.edu/program/curriculum/> |

**POST-VISIT ACTIVITIES**

**TESTABLE QUESTION RELAY** (Adapted from curriculum developed by: Erin Morgan and Laurel Heibert)

**Description:** The scientific method begins with a question. Students will play a relay race that reviews testable versus untestable questions.

**Objective:** Students will learn what makes a question testable for scientific experiments.

**Grade level:** 5th-8th

**Set up time:** 10 minutes

**Activity time:** 30 minutes

**Materials:** Testable questions card cut outs, testable and un-testable question quadrats

**Vocabulary words:** testable question, un-testable question

**Procedure:** Review the scientific method. It all begins with a question. But it is important that the question is *testable*. Discuss what is *testable* versus un-testable. Present several questions to the group: “Do sea stars like music?”, “Will hermit crabs in water always eat more food during the day than at night?”, and “Will the sea star react to food?” Why can’t these questions be tested? Emotions (“like”) can only be measured in organisms that express emotions; nonspecific language (“react”) must be defined (ie, what is a “reaction”); an investigation must take place in a specific duration (we won’t be alive “forever” or “always”). There will be 2 or 3 teams. For each team set up a “study area”—a quadrat with testable and untestable questions face-down in the squares, and an area to sort the questions.

“GO!” One student per group will race to the study area and choose a card. They must place it on the “testable” or “not testable” square print out and race back to the line to tag the next person. After half of the cards have been sorted, pause the game. Have a judge for each team review the answers. If there are mistakes, shuffle the cards together and have the team work together to sort them. Once they correctly categorize the questions they may resume the race.

\*If there are mobility issues, or if the group is low-energy, this game can be played with each team sitting around the study area and going quickly around the circle.

**Discussion Points:** Review several of the game questions, challenging the students to explain why a question was testable or not and to offer suggestions for rewriting untestable questions. Conclude the lesson by asking students to identify words that made certain game questions untestable.

Testable Question Card Cut Outs

|  |  |  |
| --- | --- | --- |
| Does a fish get **upset** if you splash in its water? | Do mussels **always** open their shells during the day? | Will hermit crabs **react** differently on land or on water? |
| Do kelp crabs **like** kelp? | Do sharks **usually** eat at night? | Do sea stars **respond** to the temperature of water? |
| Will snails be **happier** in warm water? | Do birds **often** sing to their chicks? | Are anemones **affected** by currents? |
| Do fish **swim away** when you put an object in the water? | **In a day**, how many times does a mussel open its shell? | Do hermit crabs **emerge from their shell** faster under water or on land? |
| Will kelp crabs **eat** kelp? | **In a month**, will sharks eat more food during the **day or night**? | Do sea stars **turn over** faster in warm water or cold water? |
| Will snails **move faster** in warm water or cold water? | Do birds sing to their chicks **daily** **during their first month** in the nest? | Do anemones **pull in their tentacles** when pushed by a current? |

Untestable Questions

Testable Questions

Testable Question relay—Answer Key

Untestable questions

|  |  |  |
| --- | --- | --- |
| Immeasurable Variable | Nonspecific Time Frame | Nonspecific Terminology |
| Does a fish get **upset** if you splash in its water? | Do mussels **always** open their shells during the day? | Will hermit crabs **react** differently on land or on water? |
| Do kelp crabs **like** kelp? | Do sharks **usually** eat at night? | Do sea stars **respond** to the temperature of water? |
| Will snails be **happier** in warm water? | Do birds **often** sing to their chicks? | Are anemones **affected** by currents? |

Testable questions

|  |  |  |
| --- | --- | --- |
| Measurable Variable | Specific Time Frame | Specific Terminology |
| Do fish **swim away** when you put an object in the water? | **In a day**, how many times does a mussel open its shell? | Do hermit crabs **emerge from their shell** faster under water or on land? |
| Will kelp crabs **eat** kelp? | **In a month**, will sharks eat more food during the **day or night**? | Do sea stars **turn over** faster in warm water or cold water? |
| Will snails **move faster** in warm water or cold water? | Do birds sing to their chicks **daily** **during their first month** in the nest? | Do anemones **pull in their tentacles** when pushed by a current? |

**PLOP PLOP FIZZ FIZZ** (Adapted from biologycorner.com)

**Description:** In this activity, students will learn the steps of the scientific method by conducting a basic experiment using Alka-Seltzer tablets. Students will determine what factors make a tablet dissolve faster.

**Objective**: Students will develop and test a hypothesis, analyze data, and draw conclusions. This activity will help students become familiar with the steps of the scientific method.

**Grade Level**: 4th-8th grade

**Set up time:** 10 minutes

**Activity length**: 45 minutes

**Materials:** Beakers, Alka-Seltzer tablets, tap water, warm water, cold water, salt water, vinegar, beakers, stop watch.

**Vocabulary Words:** control group, independent variable, responding variable, observation, research, hypothesis, experimental design, analyze, conclusion

**Procedure:** Print out the work sheet below and have the students record their answers as they conduct the experiment.

**Discussion Points:** Why were your results the same or different from another student’s result? Was your hypothesis correct? Why or why not? If you did this experiment again, would you do anything differently?

**Name:** \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Step 1:  Question or Observation**

**Question:   What factors will make an alka-seltzer tablet dissolve faster?**

Variables to test:   
Tap water, Warm water,  Cold water,  Salt Water,  Acidic water (using vinegar)

Of the variables above, which should serve as your CONTROL group?  \_\_\_\_\_\_\_\_\_\_

In this experiment, the independent variable is the type of water (warm, salt..etc).

What is the responding variable, or the thing you will be measuring? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Step 2: Conduct research by talking to your class mates and finding out what type of water they think Alka seltzer will dissolve faster in.**

**Step 3:  Develop a hypothesis.  Finish this statement…**

Alka seltzer will dissolve fastest in \_\_\_\_\_\_\_\_\_\_\_\_\_\_ water, and the slowest in \_\_\_\_\_\_\_\_\_ water.

**Step 4a.:  Experimental design: create your procedure.**

Answer these questions regarding your experimental procedure:

A)  Will you use a whole tablet or a half a tablet of alka seltzer?   \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_  
B)  How will you measure how quickly it dissolves?   \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

C)  How much water will you place in your beakers?  \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_  
Will this amount be the same in all of your tests?  \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_  
D)  What safety precautions should you take? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Step 4b: Experimental Design: Data Collection**

|  |  |
| --- | --- |
| Type of Water | Dissolve Time |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |

**Step 5**: Analyze Data: Look at your table, determine which type of water the tablet dissolved in the fastest time.

**Step 6:** Draw Conclusion: In a complete sentence, answer your experimental question by summarizing the data.

**Step 7:** Communicate your results to your class mates. Remember to make eye contact and speak clearly and loudly when presenting your results.

**SCIENTIFIC METHOD IN ACTION** (Activity from biologycorner.com)

**Description:** In this activity, students will read about real life applications of the scientific method.

**Objective:** Students will identify the different steps of the scientific method that were used in two different studies.

**Grade Level:** 6th-8th

**Set up time:** 5 minutes

**Activity Length:** 30 minutes

**Materials:** Printed out worksheets from below

**Vocabulary Words:** Hypothesis, experiment

**Procedure:** Print out the work sheet below and have the students record their answers.

**Discussion Points**: What should be the new hypothesis be for the BeriBeri experiment and how would you test it? The penicillin experiment lead to the development of what major medical advancement?

**Name:**\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**The Strange Case of BeriBeri**

*In 1887 a strange nerve disease attacked the people in the Dutch East Indies. The disease was beriberi. Symptoms of the disease included weakness and loss of appetite, victims often died of heart failure. Scientists thought the disease might be caused by bacteria. They injected chickens with bacteria from the blood of patients with beriberi. The injected chickens became sick. However, so did a group of chickens that were not injected with bacteria.*

*One of the scientists, Dr. Eijkman, noticed something. Before the experiment, all the chickens had eaten whole-grain rice, but during the experiment, the chickens were fed polished rice. Dr. Eijkman researched this interesting case and found that polished rice lacked thiamine, a vitamin necessary for good health.*

1. State the Problem

2. What was the hypothesis?

3. How was the hypothesis tested?

4. Should the hypothesis be supported or rejected based on the experiment?

**How Penicillin Was Discovered**

*In 1928, Sir Alexander Fleming was studying Staphylococcus bacteria growing in culture dishes. He noticed that a mold called Penicilliun was also growing in some of the dishes. A clear area existed around the mold because all the bacteria that had grown in this area had died. In the culture dishes without the mold, no clear areas were present.*

*Fleming hypothesized that the mold must be producing a chemical that killed the bacteria. He decided to isolate this substance and test it to see if it would kill bacteria. Fleming transferred the mold to a nutrient broth solution. This solution contained all the materials the mold needed to grow. After the mold grew, he removed it from the nutrient broth. Fleming then added the nutrient broth in which the mold had grown to a culture of bacteria. He observed that the bacteria died which was later used to develop antibiotics used to treat a variety of diseases.*

5. Identify the problem.

6. What was Fleming's hypothesis?

7. How was the hypothesis tested?

8. Should the hypothesis be supported or rejected based on the experiment?

**MEASURING**

Using the metric system, we measure plankton in micrometers. Have the students make measuring sticks and send them out on a measuring hike. Tell them to find things of certain lengths. Let them figure out how many microns are in the items they measure.

**WRITING THANK YOU LETTERS**

Write letters to the instructors and/or your class sponsor to tell them about the trip. When we receive letters and pictures back from the kids our instructors remember what a thrill it is to be teachers. The sponsors also enjoy getting direct feedback from the class and teacher to reinforce that they are making a difference for kids learning science. Please include the day, date and time of your trip so we can try to remember your group a little better.

**Activities/Curriculum links:**

<http://aswc.seagrant.uaf.edu/kindergarten/investigation-1.html>

|  |
| --- |
| <https://coast.noaa.gov/estuaries/curriculum/> |
| <http://www.waquoitbayreserve.org/research-monitoring/salt-marsh-carbon-project/teachers/> |
| <https://dataintheclassroom.noaa.gov/>   |  | | --- | | <http://www.noaa.gov/resource-collections/hands-on-science-activities> | | <https://coast.noaa.gov/estuaries/curriculum/human-impacts-on-estuaries-terrible-spill-in-grand-bay.html> | |
| <http://www.afterschoolalliance.org/STEM-curriculum.cfm> |
| <https://sc.club.northwestern.edu/program/curriculum/> |