Nutrients: Nutrition or Nuisance?

Adapted from: "Nutrients: Nutrition or Nuisance?" in WOW!: The Wonders of Wetlands. The Environmental Concern Inc. and the Watercourse, 1995.

Grade Level: basic

Duration: 30-40 minutes

Setting: Classroom , gymnasium

Summary: Students conduct active simulation to learn about the role of phosphorus in aquatic ecosystems.

Objectives: Students will gain an understanding of the role of phosphorus in aquatic ecosystems.

Related Module Resources:
- "Nitrates In Our Water"
- "A 'Soily' N and P"
- HANDBOOK: p. 79-90
- FIELD MANUAL: p.42-51
- Phosphorus Info./Fact Sheet
- Nitrate Info./Fact Sheet
- Phosphorus Cycle Info. Sheet
- Nitrogen Cycle Info. Sheet
- Hach Phosphate Test Kit [A-3]
- Hach Nitrate Test Kit [A-4]

Vocabulary: limiting factor, polar, algal bloom

Materials (Included in Module):
- algae, minnow, and cattail labels [B-3-envlp]
- phosphorus, soil and organic matter labels [B-3-envlp]

Additional Materials (NOT Included in Module):
- radio or cassette player or else you could sing
- chairs (though it can be done without chairs, you can use an open area).

ACADEMIC STANDARDS (ENVIRONMENT AND ECOLOGY)

7th Grade

4.1.7.B. Understand the role of the watershed.
- Explain factors that affect water quality and flow through a watershed.

4.6.7.A Explain the flows of energy and matter from organism to organism within an ecosystem.
- Demonstrate the dependency of living components in the ecosystem on the nonliving components
- Identify the relationship of abiotic and biotic components and explain their interaction in an ecosystem

4.6.7.B. Explain the concepts of cycles.
- Identify and explain cycles within an ecosystem.
- Analyze the role of different cycles within an ecosystem.

4.6.7.C Explain how ecosystems change over time.
- Explain how specific organisms may change an ecosystem

10th Grade

4.3.10.B. Explain how multiple variables determine the effects of pollution on environmental health, natural processes and human practices.
- Explain how human practices affect the quality of the water and soil.

4.6.10.A Explain the biotic and abiotic components of an ecosystem and their interaction.
- Describe how the availability of resources affects organisms in an ecosystem

4.6.10.B. Explain how cycles affect the balance in an ecosystem.
- Describe an element cycle and its role in an ecosystem.
- Explain the consequences of interrupting natural cycles.

12th Grade

4.6.12.A Analyze the interdependence of an ecosystem.
- Analyze the relationships among components of an ecosystem

4.6.12.C. Analyze how human action and natural changes affect the balance within an ecosystem.
- Analyze the effects of substances that move through natural cycles.
- Analyze the effects of natural occurrences and their effects on ecosystems.
- Analyze effects of human action on an ecosystem.

BACKGROUND:

Nutrients are essential for life. Among all of the nutrients essential for organism growth, nitrogen and phosphorus are two of the most important. Nitrogen is essential for plants to build proteins, which then can be passed along to plant-eating animals to convert to their own proteins. Phosphorus is a fundamental element for metabolic reactions of plants and animals and is a major component in nucleic acids and cell membranes.

Despite its importance, in most waterways phosphorus is found in low concentrations, therefore becoming the **limiting factor** for aquatic plant growth. The amount in water is generally no more than .1mg/L. Nitrogen

is found in several forms (ammonia, nitrite, nitrates) and is more prevalent in waterways.

Phosphorus occurs in two forms: organic and inorganic phosphates (PO_4^-). Organic phosphates are derived from living plants, animals, their by-products, and remains. Inorganic phosphates (also known as orthophosphates, free phosphates, or reactive phosphates) naturally occur and can be bound to soil particles or dissolved in water. This is because inorganic phosphate is a **polar** molecule, having a bond in which the electrons are shared unequally creating a positive and negative charge. As a result, inorganic phosphate can easily bond with other substances, such as water, sediments, organic matter, minerals, metals, or other things found in soil. Inorganic phosphates can detach from soil particles and become soluble in water (soil moisture, rain runoff, stream, or lake). At times, phosphates will remain attached to sediments accumulating on the land in soil and rocks. If washed into a waterway, phosphorus can be trapped in the sediments at the bottom of a river, lake, or ocean.

In waterways, plants and algae readily absorb inorganic phosphates, which causes them to grow rapidly. Plants absorb the phosphorus through their roots; algae, through cell walls. Animals obtain phosphorus by eating plants, plant-eaters (herbivores), or other organic matter.

Excessive phosphorus causes rapid growth in photosynthetic aquatic life such as phytoplankton (algae, some protists, and cyanobacteria), and macrophytes (flowering, leafy plants and mosses). As little as .03 mg/L of phosphates can stimulate excessive plant growth. Resulting algal blooms, or an explosive growth in algae, can turn water into a soupy green appearance. This extra plant life adds plenty of oxygen to the water, which is a good thing, but eventually those extra plants die. Then aerobic (oxygen demanding) bacteria decompose them, consuming oxygen in the process. This process is known as **eutrophication**. The resulting reduction in the water's available dissolved oxygen harms aquatic life, disrupting their ability to breathe, reproduce, and remain active. If oxygen depletion is extreme, aquatic life must move or perish.

One major problem with phosphate pollution of streams is that there is no biological process that removes dissolved phosphates from streams. The phosphates are simply absorbed into plants then released back into the water when the plants die, to be reused by other plants later.

Inputs of phosphorus into streams are derived from natural and unnatural sources. Phosphorus tends to bind to soil and sediment particles and can be washed into streams when soil erodes. Soil erosion can be natural process during rain events, especially in regions where the geologic conditions include erodible sediment or bedrock and fast flowing waters. These areas can have high phosphorus concentrations. When humans alter the land in ways that increase soil erosion (deforestation, removal of riparian zones, construction sites, poor agricultural tilling practices), an overabundance of phosphorus can enter a waterway.

Some other unnatural sources of phosphorus inputs into streams include human wastes, industrial wastes, inputs from fertilizer runoff, and the drainage of wetlands. Old,

outdated sewage treatment plants usually contribute to increased phosphorus levels in streams, especially after heavy precipitation. In some communities, drains are connected to sewage lines causing the sewage treatment plants to overflow, possibly releasing untreated sewage to a stream. Rural households with faulty septic tanks can also add phosphorus. Human waste is not the only culprit; animal waste from farms contributes, especially from livestock that graze near or even in a stream. Industries can add phosphorus when they add any organic wastes (food waste from processing plants), cleaning detergents that contain phosphates, and phosphoric acid industrial strength cleaners. Fertilizers that are placed onto lawns and crops usually contain phosphorus. If applied in excess, the phosphorus from the fertilizers is washed into streams from rain events. Phosphorus is often locked up at the bottom of lakes and wetlands, bound to the bottom sediments or metal ions that have sunk to the bottom. Any human disturbance of a wetland or lake bottom can also release this locked up phosphorus. When organic matter and soil/sediment bound phosphorus in wetland bottoms is brought to the land surface, storms can erode this new soil reintroducing the phosphorus to waterways.

OVERVIEW: In an active simulation, students will play the role of algae, cattails, and minnows to learn what happens when phosphorus is limited in waterway, when soil erosion adds extra phosphorus, and when phosphorus is in abundance.

PROCEDURE:

1. Discuss the need for phosphorus in waterways and how phosphorous is added naturally and unnaturally.

2. Have students arrange chairs in two rows, back to back, musical-chairs style. *IF YOU CANNOT USE CHAIRS or want to do this in a gymnasium or outside, the game can be musical spots instead.* Have a radio or cassette player ready to play. Improvise if you do not have one.

3. Divide the class in half. One half should get an "ALGAE" tag. The remaining half should divide between "CATTAILS" and "MINNOW" tags (equal numbers). If you make it a rule that they have to hold onto it with BOTH hands in front of them, that may limit arms flailing about when racing to chairs/spots.

4. Explain that ALGAE and aquatic plants like CATTAILS will readily take in phosphorus (inorganic phosphates) that is dissolved in the water or soil moisture. MINNOWS and other animals obtain their phosphorus by eating plants, herbivores, or other organic matter (living or once-living).

5. Indicate that the class is going to start the activity by simulating what a healthy stream ecosystem (not too many nutrients) would be like. Count out enough "P" tags (blue) for ½ the class to use. Randomly place these "P" tags on the seats of the chairs (1 per chair). *If no chairs, place the P tags on the ground, spread out, and students have to stand on them instead of sitting in chairs.* The "P"s are for the ALGAE and CATTAILS to consume only. On a few of these "P" tags, place an ORGANIC MATTER square (orange), for the MINNOWS to consume only.

6. Explain that this nutrient game is like a form of musical chairs. When the music is playing, the organisms must swim (ignore the fact that cattails don't move) in a circle around the chairs/spots. When the music stops, students must sit on a chair with available phosphorus ("P") to "take in for growth." Caution students about aggressive play. Those who do not find a "P" did not survive. You may choose to record the population of the stream for each organism on the data sheet or chalkboard after each round.

7. Conduct the **first round**. Only one half of the class will be sitting. Indicate to students that this may be the composition of a healthy stream.

8. For the **second round**, on the empty chairs/spots – place "P" tags with a SOIL particle (brown). Indicate to students that phosphorus (inorganic phosphate) readily attaches to soil particles/sediments. Rain events may erode soil into a stream, adding sediments with phosphates attached. However, ALGAE and plants like CATTAILS cannot consume phosphates if they are attached to soil particles. MINNOWS do not either. Start the second round, with the soil erosion condition locking up half the phosphorus. The result of this round should be similar to round one.

9. For the **third round**, indicate that phosphorus (inorganic phosphate) that is attached to soil particles can become soluble in water, attracted to the water molecules. Once it is dissolved in the water, it is available for plant growth. Remove all of the soil particles from the chairs/spots, but keep the "P" tags there. Conduct the round. There should be an abundance of ALGAE and CATTAILS after this round, and maybe even some more phosphorus available for even more plant growth. The excessive plant growth may be a consequence of soil erosion bringing in extra nutrients to the system.

10. For the **fourth round**, add a few ORGANIC MATTER tags to the "P" chairs/spots. With all the new plant growth, there is more food for the minnows to eat. Conduct the round. This should allow all the minnows to survive and still have a lot of plant growth remaining.

11. For the **fifth round**, indicate that the ALGAE and CATTAILS growth has ended and they are starting to die (plants don't live forever in creeks). Add a few more ORGANIC MATTER tags to the chairs. For this round, only the MINNOWS are allowed to play. They should all get seats/ spots.

12. For the **sixth round**, indicate that decomposition rates of the ALGAE and CATTAILS are increasing. Ask the class what happens to the oxygen levels of a waterway when bacteria decompose algae and plants. Oxygen levels decrease making it difficult for aquatic life, such as the MINNOWS, to survive. So for this round, the MINNOWS must swim around the chairs/spots until the music stops holding their breath. As soon as they have to breathe, they are out. Make this a very

long round so that most of the MINNOWS die. Explain that they have just simulated eutrophication conditions (nutrient enrichment causes excessive plant growth, then decomposition that lowers oxygen levels harming aquatic creatures).

13. You can continue with additional rounds, allowing students to switch tags. You may add more phosphorus to the system without the soil particles attached, indicating that other sources of nutrient pollution include sewage and industrial discharges and fertilizers washing off farm fields or lawns. The result should once again be an abundance of plant growth.

14. Review and discuss the class data. You may elect to have students make graphs of the population fluctuations from the simulation.

DISCUSSION:

Why is phosphorus (inorganic phosphates) important to a stream ecosystem? *See background information.*

What happened when phosphorus was added to the stream by soil erosion in the activity simulation? *At first, the inorganic phosphate was attached to the soil particles and was not useable by plants. It eventually became soluble in water and was used by the algae and cattails for growth and population growth. An algal bloom occurred. Eventually the plant life died and was decomposed, pulling oxygen out of the water.*

How would nutrient enrichment affect other organisms living in that ecosystem? *Nutrient enrichment causes an imbalance in the aquatic life – too much algal and plant growth. Algal blooms often shade out substrate plants and periphyton (algae on rocks). This may affect food webs and change the habitats that aquatic organisms are used to living in. Also in the activity, the fish died because of a lack of oxygen from high decomposition rates. Other aquatic creatures may also die or leave the area.*

EVALUATION:

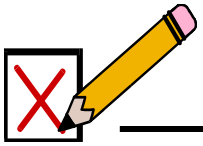
- Explain how phosphorus moves through an aquatic system (how it is used by plants and animals).
- Understand what happens when excessive amounts of phosphorus are added to waterways.
- Discussion questions above.

EXTENSIONS AND MODIFICATIONS:

- Give students a token each time they successfully find a seat. When they are "out," they must turn in their tokens. For every three tokens turned in, a chair can be added or a "P" can be freed up. This shows how nutrients are added back into the system when plants and animals die.

- Test for phosphorus in a body of water near your school. Do the nitrogen test as well, if time permits.
- Draw a poster illustrating how nutrients get into a waterway and then cycle through plants and animals.

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



DATA SHEET: NUTRIENTS: NUTRITION OR NUISANCE?

Student Name _____ Date _____

ROUND #	Stream Conditions / Phosphorus Levels	Number of ALGAE	Number of CATTAILS	Number of MINNOWS

Graphs or Notes:

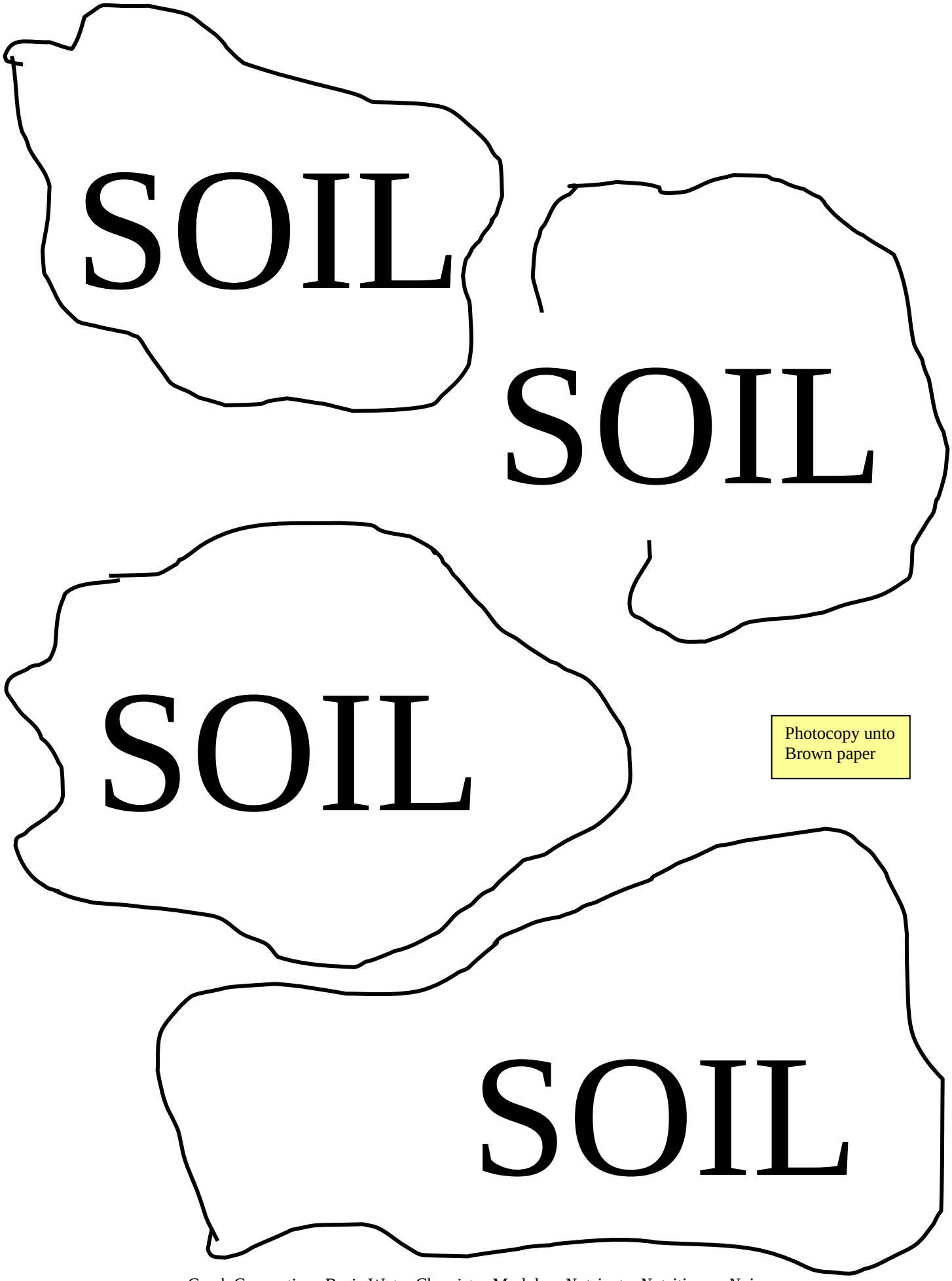
P

Phosphorus.

P

Phosphorus

Photocopy onto Blue paper


SOIL
SOIL
SOIL
SOIL
Photocopy unto
Brown paper

CATTAIL CATTAIL

CATTAIL CATTAIL

Photocopy onto green paper

MINNOW

MINNOW

MINNOW

Photocopy onto yellow paper

ALGAE

ALGAE

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ALGAE

Photocopy onto green paper

ORGANIC MATTER

ORGANIC MATTER

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Use Orange paper