Nitrogen in Ecosystems

Time: 2 class periods to begin, and then time for monitoring experiments over 6-8 weeks, with 1-2 class periods to gather and analyze final results
National Benchmarks: Benchmarks 5A: Diversity of Life; 5D Interdependence of Life; 5E: Flow of Matter and Energy; 9B:Symbolic Relationships; 9D:Uncertainty; 12B:Computation and Estimation; 12D:Communication Skills; 12E:Critical-Response Skills.
National Science Content Standards: *Science as Inquiry: A*; *Life Science: C*: Biological Evolution; The Interdependence of Organisms; Matter, Energy, and Organization in Living Systems; *Science and Technology: E:* Abilities of Technological Design; Understandings about Science and Technology; *Science in Personal and Social Perspectives: F:* Population Growth; Natural Resources: Environmental Quality; Natural and Human-induced Hazards; Science and Technology in Local, National, and Global Challenges
New York State Standards: 1, 2, 4, 5, 6, 7

Objective: Students will know the impact of various forms of nitrogen on aquatic and terrestrial ecosystems, and be able to draw a diagram showing the movement of nitrogen in these systems.

Lesson Outline:

1. Students complete the nitrogen cycle 'game' and discuss the different pathways and forms nitrogen can take in the environment.
2. Students decide if they want to investigate the impacts of excess nitrogen on aquatic or terrestrial ecosystems.
3. Students design and set up an experiment to test their hypotheses.
4. Students collect data every week, and compile this data into a lab report.

Materials:
For the game:
Copy and laminate the Nitrogen Cycle Game Descriptions, which give students the directions at each station. Make copies of the 'Nitrogen Game Worksheet' for each student. You will need one dice for each station. It helps to have pictures of the stations laminated as well.

For general class discussion:
Hudson Nutrient Cycles Powerpoint
Nitrogen Cycle Visuals
Copies of the worksheet 'Nitrogen cycle computer assignment'.

For the experiment:

Aquatic Ecosystem	Terrestrial Ecosystem
Mason jars (5-10 per group)	Plant pots, soil, radish seeds (3 per pot, remove two weakest after germination)
Pond water	Water
Measuring spoons	Graduated cylinder
Aquatic Plants: optional	Grow lights-optional

pH test kit
Fertilizer
DO test kit
1-liter containers: to prepare solutions of fertilizer, making it easier to add the treatment throughout the experimental process
Nitrate/nitrite test kits
Lab sheets: Version 1 provides less structure, while Version 2 gives students more guidance on setting up the experiment(s)

Engage: Ask students where nitrogen exists, to find out how much they understand about the nitrogen cycle. Using different photos or drawings, ask if nitrogen exists in: a plant, a person, soil, water, air.

Explore 1: Briefly explain the nitrogen 'game' they will be playing by pointing out the location of the different stations and then handing out the game sheet. Students will spend the next 20-25 minutes rotating through the stations (play the game at least 8 rounds). Give students time to draw or write about their 'journey' after finishing the game.

Explain 1: Nitrogen exists in many different forms. It is critical to organisms because it is part of proteins, chlorophyll, and genetic material (DNA, RNA, amino acids), and all organisms require nitrogen in order to live. Most exists as N2 gas in the atmosphere but plants can't use it in this form. It has to be "fixed" or converted to a form plants can use, bonded to hydrogen or oxygen to form inorganic compounds such as ammonium (NH4) and nitrate (NO3). This can be done naturally, by lightning (transforming it into nitrate which then rains onto soil) or bacteria, or by humans, in the manufacture of fertilizer and the combustion of fossil fuels. Some of the bacteria live free in the soil (releasing nitrogen during decomposition), and others which live in the root nodules of certain kinds of plants. When plants take up nitrate, they use it to make proteins, amino acids, and nucleic acids after reducing it to nitrite and then ammonium. Animals receive the nitrogen they need for metabolism, reproduction, and growth by consuming living or dead organic matter. When an animal or plant dies, or an animal excretes, the nitrogen it releases is converted into ammonia (mineralization). Ammonia is then converted into nitrates (nitrification) for use by plants. The last step in the 'cycle' is denitrification, when nitrites are reduced back into nitrogen gas by bacteria.

One of the most amazing mutualistic symbiotic relationships involves nitrogen fixing bacteria and the roots of legumes (beans, peas, and clover). The bacteria live in the root nodules and receive sugar in exchange for fixing nitrogen for the plant. Thus, the relationship is beneficial to both organisms.

An example of a nitrogen atom's pathway: An atom of N enters the watershed in an ammonium ion in rain, is converted to nitrate by bacteria in soil, washes out into the stream, is taken up by algae and incorporated into algae protein, washed downstream in dead plant, eaten by an oligochaete, eaten by a fish, passed out in feces, broken down into ammonium and then nitrate by bacteria, and then washed out to sea (use the powerpoint slide to accompany this).

Within the last century, humans have more than doubled the amount of fixed nitrogen that is pumped into the atmosphere every year. In addition to acid rain, nitrogen pollution contributes to the formation of ground level ozone (which can cause breathing problems), too much nitrogen in forests, groundwater contamination, and eutrophication of coastal waters.

Use the nitrogen cycle visuals from a disturbed and an undisturbed ecosystem in order to illustrate the impacts of humans.

Explore 2: Once students have a basic understanding of the nitrogen cycle, they should be presented with the following problem: what happens when you increase nitrogen levels in an aquatic or a terrestrial ecosystem? Allow students to work in groups to develop a hypothesis, depending on which ecosystem you would like them to investigate. Encourage them to think about how they will measure the impact (aquatic plants are a useful indicator; phytoplankton work well, but students need to think about how they will quantify their results). Students should ask for teacher approval before beginning the experimental setup. You may not want them to test both aquatic and terrestrial ecosystems; however, this provides a good measure of comparison as aquatic plants can be compared through weighing with plants that are grown from seed. Students will then set up their experiment, which should be allowed to run for several weeks. There are two different lab sheets: version 1 is more inquiry-based, while version 2 provides more structure.

Explain 2: At the end of the experiment, ask students to share their data. They should be able to draw some conclusions about the effects of different increased nitrogen on their ecosystem. Class results should be used by the students to write their lab reports.

Extend: Students complete the 'Nitrogen cycle computer assignment' based on the nitrogen cycle visuals and web research.

Evaluate: Collect students' lab reports.

Comments:

References:

Bennett, V. 2002. "Eutrophication-A Project Lab for Multi-Section Lab Courses." Tested studies for laboratory teaching, Vol 23, M.A. O'Donnell, editor. Proceedings of the 23rd Workshop Conference of the Association for Biology Laboratory Education (ABLE), 392 pages.

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