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The Greening of the Waters

Limiting Nutrients and Carrying Capacity

Grade Level	9th – 12th Grade
Subject	Science
Course	Biology, Environmental Science

Essential Question

How do limiting factors influence carrying capacity? How do changes in limiting factors affect algae growth in aquatic ecosystems?

Summary

In this lesson, students explore how the relationship between limiting nutrients and carrying capacity influence the phenomenon of algal blooms. Through an online simulation and brief research, students will understand how limiting factors influence carrying capacity in ecosystems, with specific emphasis on nutrient inputs. The lesson assumes students have prior knowledge of the definitions and relationships among populations, communities, and ecosystems; and a basic understanding of what carrying capacity is.

Snapshot

Engage

Students view examples of algal blooms in nature and an aquarium.

Explore

Students determine the limiting nutrients in various aquatic ecosystems using a simulation.

Explain

Students construct an explanation for how nutrient conditions influence an ecosystem's carrying capacity to limit population sizes.

Extend

Students explore various causes of algal blooms to make a claim about how algae are able to grow past their carrying capacity during a bloom.

Evaluate

Students write a final explanation to answer the second essential question.

Standards

Next Generation Science Standards (Grades 9, 10, 11, 12)

HS-LS2-1: Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.

Oklahoma Academic Standards (Biology)

B.LS2.1 : Use mathematical and/or computational representations to support explanations of factors that affect carrying capacities of ecosystems at different scales.

Attachments

- Ecosystem Information—The Greening of the Waters.docx
- Explanation Scaffold —The Greening of the Waters.docx
- Explore Investigation—The Greening of the Waters.docx
- Kermit—The Greening of the Waters.docx

Materials

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Engage

This lesson begins by providing examples of an algal bloom (an overgrowth of algae in water) phenomenon in an artificial and a natural environment. Start by showing students the artificial environment example of Kermit the Frog. Ask students to think about why the water might be turning green.

Teacher's Note

If you have access to a color printer, provide students with copies of the **Kermit** handout. If not, tell the story and project the images for the class to observe together. Resize the pictures as necessary.

Next, show students this time lapse video of an algal bloom in Lake Erie from 2011, one of the worst on record. Be sure to let students know that the white spots that occasionally appear over the lake are clouds passing over while the satellite was capturing photos. Once again, ask the students to think about why the water might be turning green.

At this point, explain to students the term *algal bloom* and tell them what they are observing so they have context to make a claim about the phenomenon (i.e., why the water is turning green). Algae bloom naturally on a small scale in ecosystems, but they become a problem when they grow too large, as in the video.

Pass out the **Explanation Scaffold** handout and have students record their initial explanation. Encourage students to think about what they observed about Lake Erie and Kermit, and different types of biotic and abiotic factors that could cause algae to increase or decrease in an aquatic ecosystem as they construct their explanation. Ask for a few volunteers to share out with the class. There is no need to correct any alternative conceptions or gaps in their understanding at this time.

Explore

In a class discussion, ask students to explain the similarities and differences between populations, communities, and ecosystems. You may want to ask students to take notes on this information.

It is appropriate to provide a brief explanation here of algal blooms in the context of population ecology. This is important scaffolding for the upcoming activities that does not "give away" the core concepts of the lesson. Tell students that when we see an algal bloom in an ecosystem, the bloom is (usually) a community: a mix of different species of phytoplankton (microscopic plants). During a bloom the population of each species experiences a change in the number of individual phytoplankton present. When the population(s) increase enough within the ecosystem, we are able to see them with the naked eye.

Make sure that students understand that the question they have been considering, "why is the water turning green?" is asking about what causes the community of phytoplankton populations to grow so large.

Simulating an Algal Bloom

In this activity, students will use a digital simulation to explore how nutrients impact algae growth in different aquatic ecosystems. The goal of this simulation is to determine which substance is the limiting nutrient in each aquatic ecosystem. For now, limiting nutrients can be explained to students as nutrients that have the biggest impact on population growth.

This simulation can be run on most internet browsers as well as on cell phones. The browser version is here, and a link to the mobile version can be found above the simulation window.

Have students work in pairs or small groups, depending on available technology. Student groups will select from four aquatic ecosystems: Lake Erie; the Hudson River, in New York; the Sargasso Sea, in the middle of the Atlantic Ocean; or the St. Marys River, between Florida and Georgia. Provide the appropriate **Ecosystem Information** page to each group and **Explore Investigation** handout to each student.

In the simulation, the density of algae (cells/mL) is observed over 28 days in each of the ecosystems. Students will vary the abiotic factors to see which ones produce the most algae growth. Have students manipulate the nutrients and run the simulation as many times as it takes for them to feel confident they have identified the limiting nutrient(s) in each ecosystem. They should record the data for each run of the simulation in the data table provided in their handout and by saving the images of their graphs that show their results. As a group, students should answer their conclusion question using the data to justify their claim.

Explain

Have students complete the Lines of Evidence: Simulation portion of the **Explanation Scaffold** handout. They can work as a group to describe the simulation data and interpret its meaning, but should complete the "how the simulation data supports my explanation" independently.

Ask student groups to share out a summary of their results, specifically what their limiting nutrient was and how they know. Record this information where students can see the complete class results. If technology permits, students could also share example graphs with the class during their share out. Have students independently complete the "my revised explanation of the phenomenon" section before moving on.

Discuss the following questions as a class. Consider using either the Elbow Partners or Partner Speaks strategies to scaffold discussion.

Teacher's Note: Class Discussion Questions

- What trends do you see in our data?
- How do you know a nutrient is limiting algae growth?
- What happens to the concentration of algae when the limiting nutrient is low? When it is high?
- Did the algae in your ecosystem ever reach carrying capacity? How do you know?
- How do limiting nutrients affect the algae carrying capacity in these ecosystems?

Next, provide students with information about limiting factors and their relationship with carrying capacity. This can be done through a short lecture, videos, etc. at your discretion. Students can record notes in the the Lines of Evidence: Class Notes in the Explanation Scaffold handout, or other note-taking structure used in your class. Include a formal definition of limiting factors, and definitions and examples of density dependent and density independent factors.

Teacher's Note: Video Explanations

There are a variety of videos online that discuss carrying capacity and limiting nutrients. This Carrying Capacity video and this Population Ecology video from Crash Course (0:00-8:02, emphasis on limiting nutrients from 3:16-8:02) are two effective options.

Ask students to explain for themselves how limiting factors influence carrying capacity (the first essential question), and whether nutrients are density dependent or independent and why. There is a space for this on the Explanation Scaffold handout.

Extend

Show this video of another algal bloom in Lake Erie, this time from 2017. Pose the following question to the class: if nutrients limit the carrying capacity of algae in an ecosystem (i.e., limit their population size), why can large algal blooms still occur?

Direct students to the Greening of the Waters Wakelet. In groups of 2-3, have students to explore the resources together, making note of any details that help them answer the question. How they choose to divide the work is up to the students, but consider scaffolding this activity if they need guidance for tackling group work. Complete the activity by having a class discussion where groups share out the most important information they found through their research. Before concluding the lesson, make sure to ask students to identify whether the factors they learned about are density dependent or independent.

Teacher's Note

An alternative structure to this research activity would be to use the Strike Out! strategy. Rather than the group recording their ideas on the Explanation Scaffold handout, have them record a bulleted list to be passed around to their classmates. The number of bullets will depend on how many groups you have and the amount of information you want students to develop. After the class has come up with their final list of big ideas, students should then record these on the Explanation handout and make note about how the ideas help explain the phenomenon.

Evaluate

Wrap up the lesson by having students revise their explanation for the algal bloom phenomenon one more time in the "my final explanation for the phenomenon" section of the **Explanation Scaffold** handout. This should be an evidence-based explanation, so they should use the vocabulary and concepts they developed throughout the lesson to justify and support their answer. This could be done using a CER format.

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Resources

- Harmful Algal Bloom in Lake Erie July November 2011 https://youtu.be/umk7m3MWwUo
- Jon Darkow simulation https://sites.google.com/site/biologydarkow/ecology/limiting-nutrients-with-data-analysis
- Carrying Capacity https://www.youtube.com/watch?v=O9_gi3AMcok
- Population Ecology: The Texas Mosquito Mystery - Crash Course Ecology #2 https://youtu.be/RBOsqmBQBQk
- Satellite Image of a Phytoplankton bloom in Lake Erie https://youtu.be/DwmiWSOPNMQ
- Claim, Evidence, Reasoning (CER) https://learn.k20center.ou.edu/strategy/156