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Trees of the Seas

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TREES OF THE SEAS

PHYTOPLANKTON AND EUTROPHICATION: THE CAUSE OF HARMFUL ALGAL BLOOMS

Michelle Woods
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Grade Level
7th Grade

Subject Area
Life Science

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Title The Trees of the Seas

Focus Phytoplankton and Eutrophication: The Cause of Harmful Algal Blooms.

Grade Level 7th Grade Life Science

VA Science Standards

- LS.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which a classification system is developed based on multiple attributes; models and simulations are constructed and used to illustrate and explain phenomena; dependent variables, independent variables, and constants are identified; variables are organized, communicated through graphical representation, interpreted, and used to make predictions; patterns are identified in data and are interpreted and evaluated; and current applications are used to reinforce life science concepts.
- LS.5 The student will investigate and understand the basic physical and chemical processes of photosynthesis and its importance to plant and animal life. Key concepts include photosynthesis as the foundation of virtually all food webs.
- LS.6 The student will investigate and understand that organisms within an ecosystem are dependent on one another and on nonliving components of the environment. Key concepts include the carbon, water, and nitrogen cycles and complex relationships within terrestrial, freshwater, and marine ecosystems.
- LS.10 The student will investigate and understand that ecosystems, communities, populations, and organisms are dynamic, change over time, and respond to daily, seasonal, and long-term changes in their environment. Key concepts include eutrophication, climate changes, and catastrophic disturbances.
- LS.11 The student will investigate and understand the relationship between ecosystem dynamics and human activity. Key concepts include factors that threaten or enhance species survival; and environmental issues.

Learning Objectives

- Students will explain how eutrophication causes harmful algal blooms.
- Students will run their own experiments and generate their own data to understand eutrophication and its impacts on phytoplankton.
- Students will graph their own data.
- Students will compare their data to other students' data in the class.
- Students will discuss strategies for preventing harmful algal blooms.

Total length of time required for the lesson Two 45-minute class periods with one week in between each class (i.e. Monday through Monday). 5-10 minutes per day during each class period throughout the week will also be needed.

Key words, vocabulary

water column; photosynthetic; primary producers; harmful algal blooms (HABs); estuaries; anthropogenic; nutrient loading; eutrophication; microbes; dead zones; management actions; mitigation; prevention; control

Phytoplankton: microscopic, one-celled organisms that live within the water column

Water column: amount of water from the surface to the bottom of the ocean

Photosynthetic: plants, like phytoplankton, that use carbon dioxide, nutrients, and energy from light to make energy to survive

Primary producers: organisms that make their own energy needed for growth and survival through photosynthesis

Harmful algal blooms (HABs): population explosions of phytoplankton because of changing seasons and the increased availability of nutrients such as nitrogen and phosphorous; cause negative effects to humans and/or other organisms

Estuaries: coastal systems that are a mix of freshwater and saltwater

Anthropogenic: human influence

Nutrient loading: the amount of nutrients (nitrogen and phosphorous) entering a coastal system in a given period of time

Eutrophication: the excessive growth of algae due to an increase in nutrient loading

Microbes: a microorganism such as bacteria

Dead zones: an area in the water column where there is not enough oxygen to support life

Management actions: plans to solve a problem, like HABs

Mitigation: dealing with an existing bloom and taking steps to reduce negative impacts

Prevention: actions taken to keep HABs from happening or impacting a particular resource

Control: actions taken to combat or suppress HABs

Background Information

Phytoplankton are microscopic (tiny), single-celled organisms that live in the **water column**. Phytoplankton, like plants on land, are **photosynthetic**. This means that phytoplankton use carbon dioxide, nutrients, and energy from light to grow. Photosynthesis makes oxygen, which is important for other animals. Phytoplankton are **primary producers**. This means that they make their own energy needed to grow and live. As phytoplankton need light to grow, they live in parts of the ocean where sunlight reaches. Phytoplankton are some of the most important organisms on earth as they make about half of the atmosphere's oxygen. All animals, including humans, need oxygen to survive! Phytoplankton are also food for many other animals in the ocean.

Sometimes phytoplankton grow out of control. This causes harm to ecosystems! This is what scientists refer to as a **harmful algal bloom**, or **HABs** for short. HABs happen when there is a huge increase in the amount of phytoplankton because of changing seasons and more nutrients in the water. These nutrients are nitrogen and phosphorous. HABs happen in coastal areas such as **estuaries** because of human, or **anthropogenic**, activities. These activities lead to more runoff of nutrients. These can come from pet waste, household products, fertilizer use, storm water, waste water, septic systems, fossil fuel use, and urbanization (which increases the amount of hard/paved surfaces and increases runoff into coastal waters). This increase in **nutrient loading** into the water causes **eutrophication**. Eutrophication is the excessive growth of algae. Enough eutrophication can lead to more HABs happening.

HABs impact the ocean in many ways. HABs can harm both humans and other animals. HABs can use up oxygen in the water. Phytoplankton make oxygen through photosynthesis but when phytoplankton cells die, **microbes** use oxygen to get energy from the dead cells. This uses up oxygen in the water and makes **dead zones**. This can lead to the death of other animals in the ocean such as fish, shellfish, and marine mammals. Some species of phytoplankton also make toxins that can cause humans and marine animals to get sick. HABs can also impact human economies as they can cause economic loss in the seafood industry and tourist communities.

Scientists want to understand what causes HABs and how to prevent HABs from happening in our oceans. There are many **management actions** people can take to solve the HABs problem. These management actions include:

- **Mitigation:** dealing with a bloom that exists and taking steps to reduce the negative impacts. Examples include monitoring programs for toxins in shellfish or towing fish net pens away from sites of HABs.
- **Prevention:** actions to keep HABs from happening or impacting resources. Examples include policy changes to decrease use of fertilizer and fossil fuels, creating more waste water treatment plants, and decreasing septic system use.
- **Control:** actions taken to combat or suppress HABs such as biological, chemical, genetic, and environmental control. Examples include removal of HABs cells by dispersing clay over the water surface and causing the cells to sink to the bottom where light does not reach.

Student handouts and other materials needed

Appendix 1: First Class Period Worksheet

Appendix 2: Second Class Period Worksheet

Supplementary PowerPoint

Materials & Supplies

For the lesson, the instructor will need a computer and a projector for the PowerPoint slides. The class will be divided into five groups. For the activity, the instructor will need the following:

- 15 1-liter clear plastic bottles (three per group; cleaned, label taken off, and water line marked just below the start of the neck so that there is some headspace in the bottles)
- Miracle-GRO Pour and Feed Plant Food (liquid fertilizer)
- Water: purified water (or DI), water from a local water source (river, pond, lake, estuary)
- Phytoplankton growth kit (optional)
- 10 cups (two per group, one to pour water and one for the liquid fertilizer)
- Cameras (one per group; cell phones, iPads, etc.)
- 5 rolls of masking tape (one per group)
- 5 sharpies (one per group)
- 5 tablespoons (one per group)

Individual group materials (each of the 5 groups should have the following materials):

- 3 1-liter bottles
- 1 cup filled with liquid fertilizer
- 1 empty cup to pour water
- 1 camera
- 1 roll of masking tape
- 1 sharpie
- 1 tablespoon

Classroom/Lab/Field Study Setup

Students will work in small groups for this project (split the class into 5 groups). Students will be growing phytoplankton, so access to natural sunlight is important (ex: a table by a window, windowsills in the hallways or classrooms, a greenhouse if accessible). The bottles will be set up for a week (i.e. Monday through Monday) with students checking on them every day (Monday through Friday), so the space where the bottles are kept should be easily accessible, but out of the way for others.

General Procedure:

Advanced preparation of lab materials – 60 minutes

- Gather and clean clear plastic bottles (1-liter disposable plastic water bottles)
- Obtain purified water (Walmart or through DI water source if available in the lab space at school)
- Purchase Miracle-GRO Pour and Feed Plant Food (can be found on Amazon or at Walmart).
- Mark each bottle with a line to where the students will fill with water (just below the start of the neck so that there is some headspace in the bottles). The red line on the image below marks

approximately where the water line should be marked. This marking position will stay the same regardless of water bottle size/type.



- Collect water from a local water source (ex: river, stream, lake, pond, wetland, or estuary) OR purchase an algae culture kit (Amazon has options from Algae Research Supply or, if applicable, instructors can go through their school's research supply company) to ensure phytoplankton exists within the water.
- If instructors would like to collect water from a local water source, this lesson should be conducted in the early fall or late spring when natural algal populations are high in local water bodies. During the winter, phytoplankton numbers are low and it would be better to use an algae culture kit. It is recommended that the water be collected in 5-gallon buckets so that students can fill their own bottles with water during the activity. The instructor will need enough water to fill 10 1-liter bottles. The water should be collected the night before or the morning of the experiment day and left uncapped and in the open so that it remains aerated for the experiment. DI or purified water should be obtained and stored in a bucket or the container it came in. The instructor will need enough purified or DI water to fill 5 1-liter bottles.
- If instructors choose to use an algae culturing kit, it will take an additional 2 weeks to culture and have sufficient algal growth for the experiment. If purchasing an Algal Research Supply algae growth kit, instructions and all supplies (aside from water) are provided with the kit. Instructors can choose which strain of algae to purchase.

Lab set-up – 10 minutes

- Place 3 1-liter bottles at each group's workspace
- Place a role of masking tape, a sharpie, and a cup to be used to fill bottles with water from the bucket it was collected in.
- Provide cups of Miracle-GRO liquid fertilizer and tablespoon at each group's workspace.

First Class Period Procedure:

Introduction – 10 minutes

- Present the first half of the accompanying PowerPoint slides.
- Separate the class into groups of 3 or 4 (there should be 5 groups total)
- Pass out the Appendix 1: First Class Period Worksheet.

Activity – 30 minutes

- The class should be following the instructions and answering the questions as they go on Appendix 1: First Class Period Worksheet.
- Each group will fill one bottle with DI/purified water, and two bottles with local, natural water using the cups at their workspace and taking from the buckets the instructor collected water in. Each bottle should be filled to the pre-marked line (as described above).
- The purified water bottle and one of the bottles with local water should receive no Miracle-GRO liquid and should be labeled with masking tape and a sharpie accordingly.
- Each group will add a designated amount of Miracle-GRO liquid fertilizer to the third bottle that contains local water.
 - Each group will add a different amount. For example: group one will add 1 tablespoon, group 2 will add 2 tablespoons, group 3 will add 3 tablespoons, etc. The bottles will then be labeled with the water source and how much fertilizer it contains.
- Have the students cap their bottles and shake them well to make sure the fertilizer is dispersed.
- The groups will then uncap their bottles, take pictures of all three of their bottles (with labels showing in the pictures), and place the bottles in an area that is well-lit with natural sunlight.
- If the instructor chooses to use an algae culture kit, have all of the students fill their bottles with purified/DI water. Two out of the three bottles should receive algae from the culturing kit. The same procedure as above should be followed when adding the Miracle-GRO liquid fertilizer as well as monitoring the growth of the algae and completing the rest of the activities.

Breakdown and Clean-up – 5 minutes

All materials and worksheets should be returned to the instructor. Bottles will remain placed in the well-lit area for one week.

Experiment Week Class Period Procedure:

Activity – 5 to 10 minutes

- The bottles will stay in the well-lit area for a week and every day at the beginning or end of class, the students will take pictures of all 3 bottles. Make sure that the surface behind the pictures is white (students can hold a white piece of paper behind each bottle) so that the color change/bubble creation is easily observed. If algal growth is not noticeable, the instructor can carry on the experiment for a second week, with the students taking pictures at the beginning or end of class of all 3 bottles.
- At the end of the week (or second week if the experiment was extended), the instructor should have access to all of the pictures so that they can be printed out for the second class period for the students to analyze. Instructors can choose to keep the pictures on the phones or iPads for the students to analyze if they feel that would be easier.

Second Class Period Procedure:

Introduction- 5 minutes

Show the students the first slide of the second part of the PowerPoint.

Activity/Discussion - 35 minutes

- Have the students reconvene in their groups.
- Hand out Appendix 2: Second Class Period Worksheet and each groups' printed or digital pictures.
- Have the students complete the first page of the Appendix 2: Second Class Period Worksheet. If the teacher has high-achieving students, those students could be asked to create their own graph instead of using the template provided on the first page of Appendix 2.
 - If two weeks were used for the experiment, have the students graph the results from every other day, instead of every day. To make this easier for the students, the graphs can be amended to read "Day 2, Day 4, Day 6, Day 8, Day 10".
- After the first page is completed, have the groups share their results with the whole class.
 - The instructor will graph the group results on the "Phytoplankton Abundance Day 5 – Class Data" graph included on the PowerPoint. The graph can be projected onto the white board and filled in with dry erase markers, or if the instructor has a Smartboard, the graph can be projected and filled in on that. Note that if 2 weeks were used for the experiment, Day 5 corresponds to Day 10.
- After the class graph is filled out, each group will answer the questions 1-3 on the second page of the worksheet. The class can then discuss their answers together and compare ideas and results.
- Show them the last PowerPoint slide and have them answer question 4 either in groups or independently. Have them share with the class if there is time!

Breakdown and Clean-up – 5 minutes

The students will dump the contents of the bottles down the drain or outside and return the bottles to the instructor for reuse.

Assessment

The instructor will base assessment of the effectiveness of the activity on analyzing questions and graphs created from the data worksheet and the question worksheet that students will hand in at the end of the second class (end of the week long experiment). The instructor can also base assessment on the answers given during the in-class discussion.

References

These references provide more information on phytoplankton, HABs, and eutrophication.

- Phytoplankton – A Simple Guide: <https://www.whoi.edu/know-your-ocean/ocean-topics/ocean-life/phytoplankton/>
- Why do harmful algal blooms occur: https://oceanservice.noaa.gov/facts/why_habs.html
- What is eutrophication: <https://oceanservice.noaa.gov/facts/eutrophication.html>
- Eutrophication: Causes, Consequences, and Controls in Aquatic Ecosystems: <https://www.nature.com/scitable/knowledge/library/eutrophication-causes-consequences-and-controls-in-aquatic-102364466/>
- Approaches to monitoring, control, and management of harmful algal blooms (HABs): <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2818325/>

Image Source Inventory

publicdomainvectors.org

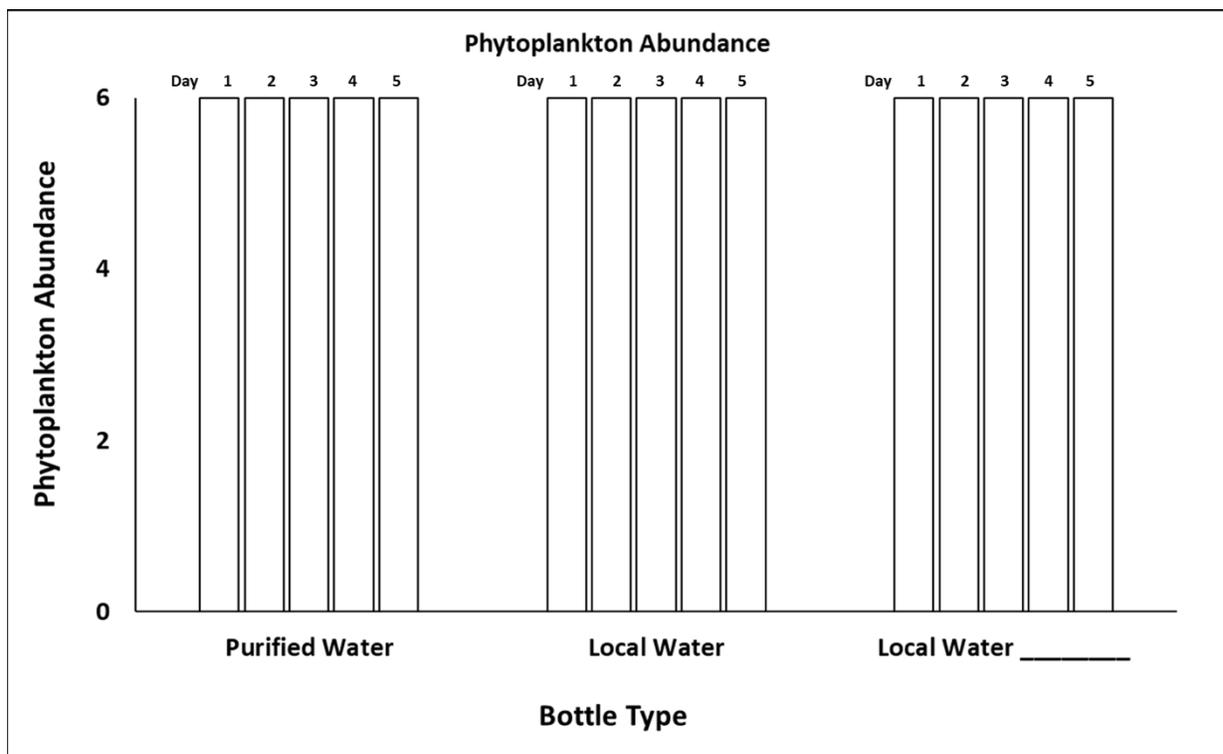
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Appendix 2: SECOND CLASS PERIOD WORKSHEET

GRAPHING THE DATA

Fill in the X axis to indicate how much Miracle-GRO you added to your third bottle. Look at your pictures you took throughout the week (either on the device you took pictures on or print outs if your instructor printed your photos). Rank the amount of color you see in each bottle in each picture according to the number scale below (the same number can be used for multiple bottles and it is ok if the number doesn't change from day to day!). If you do not see any color, you can rank the amount of bubbles in each bottle using the same number scale. You might have to look closely at your pictures or zoom in for this! Once each bottle in each picture has a number corresponded to it, fill in the bars of the graph to illustrate the amount of phytoplankton in each bottle.



Color/Bubbles	Number on Graph	Corresponding Phytoplankton Abundance
None	0	No phytoplankton
Light green/A little	2	Low abundance
Medium green/Medium	4	Medium abundance
Darker green/A lot	6	High abundance

SECOND CLASS PERIOD WORKSHEET CONTINUED

THINK ABOUT THE DATA

Now that you have collected your data and compared your values with the class, it is time to interpret the results. Work within in your groups to answer the questions below.

1. Describe the trend you see on the class graph. How did increasing the amount of fertilizer change the amount of phytoplankton that grew in the bottles? Does this match your predictions from the start of the experiment?
2. Why can you use bubbles as indicator of phytoplankton abundance, even if color isn't present?
3. How does adding the Miracle-GRO fertilizer relate to what is observed in nature with eutrophication and harmful algal blooms?
4. Based on the strategies talked about with the class, what would be the best method for reducing the impacts of eutrophication? Do you have any ideas for how to combat HABs?

Appendix 1: FIRST CLASS PERIOD WORKSHEET **Answer Key**

INSTRUCTIONS

- Fill one bottle with purified water and fill two bottles with local water that your instructor collected. Each bottle should be filled to the marked line.
- Label each bottle with what type of water it received.
- Set the purified water bottle and one of the local water bottles aside.
- Add the amount of Miracle-GRO Pour and Feed your instructor assigned to your group into the local water bottle still in front of you. Make sure to mark on the label how much fertilizer you added!
- Cap your bottles and shake them well to make sure the fertilizer mixes in!
- Uncap your bottles and place the bottles in a well sunlight area that your instructor has designated. Make sure you give the caps back to your instructor.

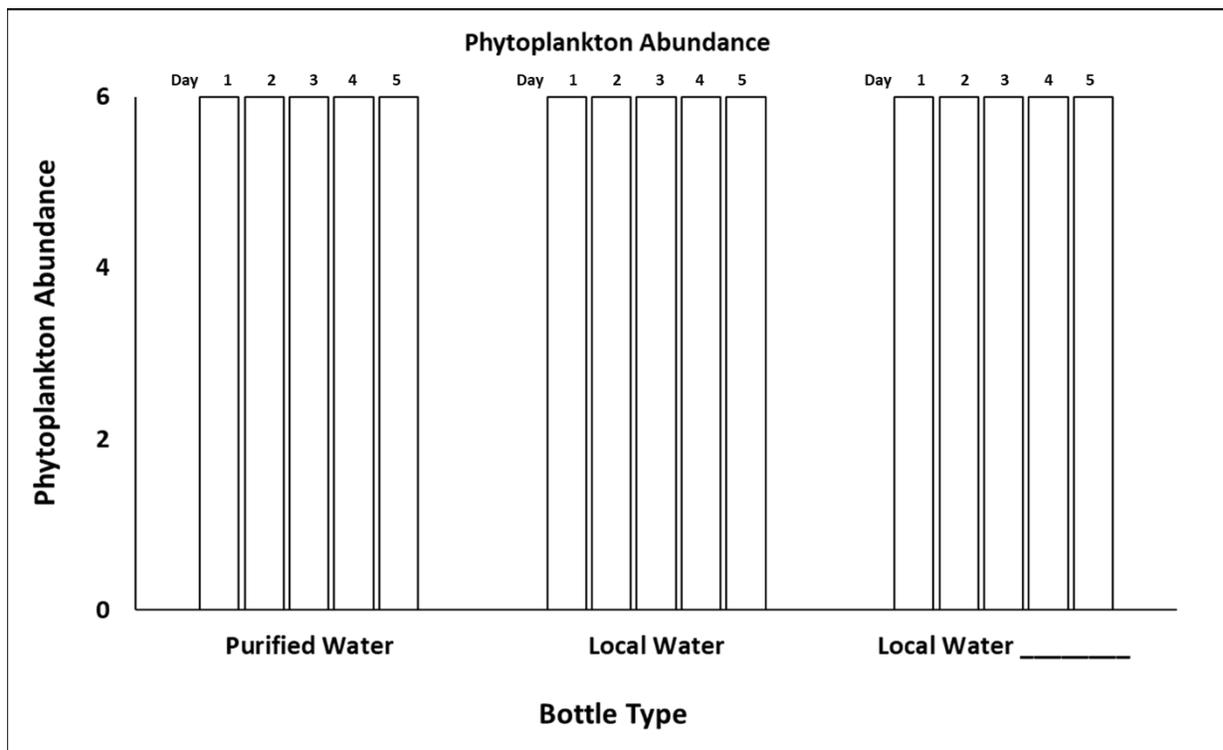
THINKING ABOUT THE EXPERIMENT

1. Which bottle do you expect to have the most amount of phytoplankton growth? Which bottle do you expect to have the least amount of phytoplankton growth? Explain why.
The students should expect the bottle with the added Miracle GRO fertilizer to have the most amount of phytoplankton growth because the fertilizer contains nitrogen and phosphorous nutrients that phytoplankton need to photosynthesize and grow. The bottle with the purified water and no fertilizer should have the least amount of phytoplankton growth because there is no algae or nutrients in the water.
2. What is the purpose of adding the Miracle-GRO Pour and Feed fertilizer to one of the bottles? Do you think this will promote phytoplankton growth?
Adding the Miracle GRO fertilizer acts as a source of eutrophication, much like fertilizer runoff from land into coastal waters. The students should expect this to promote phytoplankton growth, much like in the case of harmful algal blooms in response to eutrophication.
3. How might we monitor/measure the growth of phytoplankton in our bottles?
Phytoplankton can be measured by the color that you see when phytoplankton grow (the students should be able to extrapolate this answer from the many pictures they saw during the introduction PowerPoint).

Appendix 2: SECOND CLASS PERIOD WORKSHEET

GRAPHING THE DATA

Fill in the X axis to indicate how much Miracle-GRO you added to your third bottle. Look at your pictures you took throughout the week (either on the device you took pictures on or print outs if your instructor printed your photos). Rank the amount of color you see in each bottle in each picture according to the number scale below (the same number can be used for multiple bottles and it is ok if the number doesn't change from day to day!). If you do not see any color, you can rank the amount of bubbles in each bottle using the same number scale. You might have to look closely at your pictures or zoom in for this! Once each bottle in each picture has a number corresponded to it, fill in the bars of the graph to illustrate the amount of phytoplankton in each bottle per day.



The purified water bars should all be equal to 0, the local water only bars should be equal to 2 or 4 by the end of the week, and the local water bars with fertilizer should be equal to anywhere from 2 to 6 by the end of the week depending on how much fertilizer was added (more fertilizer = more growth).

Color/Bubbles	Number on Graph	Corresponding Phytoplankton Abundance
None	0	No phytoplankton
Light green/A little	2	Low abundance
Medium green/Medium	4	Medium abundance
Darker green/A lot	6	High abundance

SECOND CLASS PERIOD WORKSHEET CONTINUED

THINK ABOUT THE DATA

Now that you have collected your data and compared your values with the class, it is time to interpret the results. Work within in your groups to answer the questions below.

1. Describe the trend you see on the class graph. How did increasing the amount of fertilizer change the amount of phytoplankton that grew in the bottles? Does this match your predictions from the start of the experiment?

The students should recognize that adding more fertilizer increases the amount of phytoplankton present. They should recognize that the local water source already has phytoplankton in it, which is why some growth is observed in those bottles. More growth is observed in the bottles with fertilizer because nutrients are provided that help the phytoplankton photosynthesize and grow.

2. Why can you use bubbles as indicator of phytoplankton abundance, even if color isn't present?

The students might have trouble answering this question, but ask them if they remember what important molecule is produced during photosynthesis that humans rely on. They should say oxygen! The bubbles are the sign that oxygen is being produced within the bottles, indicating that photosynthesis is occurring. We can extrapolate that the more bubbles are equal to higher rates of photosynthesis occurring and that there are more phytoplankton present!

3. How does adding the Miracle-GRO fertilizer relate to what is observed in nature with eutrophication and harmful algal blooms?

Adding the Miracle-GRO fertilizer is simulating what happens when nutrients runoff from land into the water. The increased phytoplankton abundance observed with increasing fertilizer addition is analogous to eutrophication and the HABs that occur as a result of increased nutrient loading.

4. Based on the strategies talked about with the class, what would be the best method for reducing the impacts of eutrophication? Do you have any ideas for how to combat HABs?

This is more of an open-ended question and it can be fun to see what the students come up with to solve this complex environmental problem!