



Unit Title: Phosphorus and Algal Blooms

Subject/Target grade: Biology 9

Unit Summary:

Students will learn (or review) what a watershed is and will be able to identify their watershed. Surface water will be defined and students will give examples. Students will learn about eutrophication and phosphorus as the limiting factor for algal growth in lakes. They will learn how to graph data and use criteria to define the trophic state of a lake and how that can impact algal growth and potentially cause harmful algal blooms (HABs). They will be able to define different types of HABs and what problems they can cause. The summer 2013 HAB in western Lake Erie and its effects on Toledo residents will be discussed as an example. Students will graph and interpret given data and test model simulations for different scenarios relevant to managing phosphorus loads to a lake. Understanding interactions between nutrients, algal growth, and human activity will benefit students in future decision making in their personal lives and also stimulate higher level thinking about how to solve environmental problems that impact whole communities.

Prior knowledge the students will need to master the learning objectives include reading and writing skills as well as basic knowledge of Excel and PowerPoint or similar software. Unit conversions may be reviewed. There will be a short review of how to create graphs in Excel and slides in PowerPoint, but it should not be the first time that students are using the programs. Students should also know the parts of a dissecting scope and how to use the instrument. This may also be reviewed.

Next Generation Science Standards:

HS-ESS2-2	Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.
HS-LS2-2	Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.
HS-LS2-7	Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.
HS-LS4-6	Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.
HS-LS4-5	Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.
HS-ETS1-1	Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.
HS-ETS1-3	Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.
HS-ETS1-4	Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

Learning Objectives:

Students will be able to:

- I. Define the term watershed.
- II. Identify watersheds in Michigan and the whole Great Lakes basin.
- III. Identify and give examples of physical features of a watershed.
- IV. Explain why scientists and engineers use watershed and lake models simulating trophic state and how such models can be useful.
- V. Define land use and identify different land uses in the Great Lakes basin.
- VI. Explain how population density and land use can be related.
- VII. Give examples of surface water uses.
- VIII. Define and give examples of point sources and non-point sources of phosphorus.
- IX. Discuss how different land uses can affect a water body and associated organisms.
- X. Prepare a presentation describing a water pollution problem and potential remediation strategies.
- XI. Identify trends in phosphorus and chlorophyll levels in Lake Ontario over time.
- XII. Define the trophic state of Lake Ontario and how it has changed over time.
- XIII. Explain how trophic state can be defined using different metrics (phosphorus, chlorophyll, dissolved oxygen, abundance of macrophytes, Secchi disk, etc.).
- XIV. Use data plotting/graphing tools in Microsoft Excel.
- XV. Explain what harmful algal blooms (HABs) are and what problems they cause.
- XVI. Name and describe at least 2 different types of HABs.
- XVII. Identify and describe how different types of nutrient sources promote algal growth.
- XVIII. Discuss what people can do to reduce phosphorus loads to lakes and thus curb algal growth.
- XIX. Use a model to simulate how Secchi depth (water clarity) can be increased in a fictional lake.
- XX. Describe the impact of phosphorus in agricultural runoff and wastewater discharges on trophic state and algal growth.

- a. Describe the impact of land slope on Secchi depth.
 - b. Describe the impact of land use (cropland vs. pasture) on Secchi depth.
 - c. Describe the impact of wastewater treatment plant P discharges (point source P loading) on Secchi depth.
- XXI. Present modeling results with the aid of prepared PowerPoint slides to practice professionalism in front of a formal audience.
- XXII. Provide sound evidence and support (based on output from the provided model) for different options to increase Secchi depth.

Table of Lessons

Lesson Title- Brief Description	Learning Objectives	NGSS Addressed (codes)	Materials
<p>1. Watersheds and Surface Waters</p> <p><i>Students will define and describe watersheds and effects of land use on surface water.</i></p>	I, II, III, IV	HS-ESS2-2 HS-LS2-7	<ul style="list-style-type: none"> • GW_Unit1_Lesson1_Watersheds.pdf • Slides (Watersheds.pptx, LandUse.pptx) • Handouts (WatershedModelingActivity.pdf, StudentSheet_WaterPollution.pdf, WaterPollutionPresentationRubric.pdf) • WaterPollutionTeacherCheatSheet.pdf • Computer, projector, document camera • Internet access
<p>2. Trophic State in Lake Ontario</p> <p><i>Students will learn about algal growth, Liebig's Law of the Minimum, and defining trophic state.</i></p>	V, VI, VII, VIII	HS-LS2-7 HS-LS4-5 HS-ETS1-1	<ul style="list-style-type: none"> • GW_Unit1_Lesson2_Trophic_State.pdf • Slides (TrophicState.pptx) • Handouts (StudentSheetTrophicState.pdf, InstructionalRubricTrophicState.pdf, Layman's Guide for Measuring Trophic State.pdf, TrophicState_Data.xlsx) • TrophicState_SampleSolution.xlsx • Computer, projector, document camera • Internet access • Microsoft Office suite • Laboratory with microscopes • Algae samples (maybe from potential field trip) • Laptops/PCs for data processing activity
<p>3. Harmful Algal Blooms and Phosphorus</p> <p><i>Students will research different types of HABs and discuss different P sources.</i></p>	IX, X, XI, XII	HS-LS4-5 HS-ETS1-1	<ul style="list-style-type: none"> • Slides (HABs and P Sources.pptx) • Handouts (StudentSheet_HABs.pdf, P Limitation.pdf) • Sample answers (Solutions HABs Summary.pdf, Solutions P Limitation.pdf) • Computer, projector, document viewer • Internet access • Microsoft Office suite

<p>4. Surface Water Modeling</p> <p><i>Students will apply a provided model to test different management options to increase Secchi depth and curb or reverse cultural eutrophication.</i></p>	<p>XIII, XIV, XV, XVI</p>	<p>HS-LS4-6</p> <p>HS-ETS1-3</p> <p>HS-ETS1-4</p>	<ul style="list-style-type: none"> • Slides (Surface_Water_Modeling.pptx) • Handouts (StudentSheet_Surface_Water_Modeling.pdf) • Sample_Solution_Surface_Water_Modeling.pdf • Computer, projector, document camera • Microsoft Office suite • Laptops/PCs with Internet access for model simulation activity
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Lesson 1: First, students will learn or review what a watershed is and to recognize their own watershed on a map. Students will create model watersheds and identify physical features. Examples of surface waters in their watershed will be identified. The definition and examples of land use will be discussed and students will learn the definition of point and non-point sources of pollutants. Students will research a polluted water body and present findings on potential remediation strategies. This will prepare the students for upcoming lessons focusing on algal growth and trophic state of lakes.

Lesson 2: This lesson serves to establish general knowledge of algal requirements for growth in terms of light, temperature, substrate, and nutrients. Different types of algae will be introduced (phytoplankton, benthic macroalgae) and students will use microscopes to take a look at the cell shapes of different algae samples. If time and logistics permit, there may be a field trip on MTU's *R/V Agassiz* during which we can take phytoplankton samples and identify algae in the MTU limnology lab using a high power microscope. Liebig's Law of the Minimum will be discussed and students will become familiar with the idea of phosphorus as the limiting nutrient for algal growth in lakes. Students will learn how lakes are classified into different trophic states: eutrophic, mesotrophic, or oligotrophic. There are several different metrics (nutrients, water clarity, chlorophyll concentrations, oxygen levels, etc.) that can be used to define trophic state. Students will do a high level task given a dataset of phosphorus and chlorophyll concentrations measured over the years in Lake Ontario. Students will plot and interpret the data in order to apply and expand their graphing skills using Microsoft Excel as well as define the trophic state of Lake Ontario according to provided criteria.

Lesson 3: Students will learn about harmful algal blooms (HABs) through the example of the water ban in Toledo in the summer of 2014. The concept of non-harmful nuisance blooms such as in the case of *Cladophora* in Lake Ontario near Toronto may also be discussed based on images, news stories, and videos. There will be a review of required conditions for algal growth and then a discussion of phosphorus sources supported by guiding questions and images. The students will perform a research activity to identify and describe aspects of different HABs and management approaches for curbing phosphorus loads from different sources.

Lesson 4: In this lesson, we will review some solutions that have been developed to curb algal growth and improve water quality, which students researched in the previous lesson. A question-based discussion will help students understand costs and benefits of changing agricultural practices and

wastewater treatment plant processes. Other factors such as urban and stormwater runoff contributing to phosphorus loads into the Great Lakes will also be reviewed. Students will use a model that can be run online to simulate how the trophic status of a lake changes with changing phosphorus loads based on agricultural runoff and wastewater treatment plant discharges.

Safety Considerations: Students will be respectful and follow lab safety rules when looking at algae under the microscope. Students will behave responsibly when using laptops in the classroom or PCs in the computer lab.

Evaluation Plan: At the end of the trimester, the unit will be assessed through exam questions covering the main concepts of watersheds and surface water characteristics, algal growth factors, Liebig's Law of the Minimum, HABs, trophic state, and human impacts on trophic state. This will require students to review the material on their own in preparation for the exam and the act of reading questions and individually writing out answers (short and in paragraph form) during the exam will reinforce the material covered in the unit.

Lesson 1: Verbal assessment through questions and participation in identifying watersheds and surface water characteristics and how changes in those can affect various Earth systems. A written task sheet may be used to guide or facilitate discussion of watersheds and land use. Students will be asked to sketch a diagram showing point and non-point sources of phosphorus to reinforce their understanding. Finally, students will prepare a PowerPoint presentation describing a polluted water body and potential remediation strategies.

Lesson 2: Half of the groups will present their work via PowerPoint to the class, while the other groups prepare a short (1-2 page) report to describe their data analysis and interpretation. The report will require students to formally write and organize their procedures, ideas, and results, as would be expected by a client in the real world.

Lesson 3: The half of the groups that did not present for Lesson 2 will present their work via PowerPoint to the class this time, while the remaining groups prepare a short (1-2 page) report to describe their data analysis and interpretation. (This way everyone will have prepared a presentation and a report by the end of the unit.)

Lesson 4: Presentation of model simulation results to the class (acting as the city council). The presentation will require students to verbally explain their procedures, ideas, and results to their "client."

Resources (websites):

Information on characterizing watersheds and water bodies:

<http://www.ecy.wa.gov/programs/wq/plants/management/manual/chapter6.html>

Laymen's Guide for Measuring a Lake's Trophic State:

<http://des.nh.gov/organization/commissioner/pip/factsheets/bb/documents/bb-27.pdf>

NOAA lesson on HABs:

<http://www.habmap.info/docs/Harmful%20Algal%20Blooms.pdf>

EPA website:

<http://www2.epa.gov/nutrientpollution/sources-and-solutions>

Lake Water Quality Simulator:

<http://techalive.mtu.edu/envengtext/LakeWQSimulator.swf>

****Brief description of how this unit relates to your graduate research. (1 page):**

A unit on water quality specifically with a focus on nutrients and algae directly relates to my research on *Cladophora*, a filamentous green alga native to the Great Lakes that is currently growing at nuisance levels due to excessive phosphorus loads in Lake Ontario. It is important that students understand the role that phosphorus plays as a limiting factor in algal growth and they should be able to discuss what problems are associated with HABs and other nuisance algae blooms. In this unit, current or recent events such as the HAB in Lake Erie, which left >200,000 people in Toledo without reliable tap water in the summer of 2014, should be discussed. Students may not realize where their drinking water comes from, so a brief activity requiring them to find out may also be appropriate.

The focus of my research is not on cyanobacteria and phytoplankton but on *Cladophora*, which is a macroalga that grows at nuisance levels in Lake Ontario by Ajax, ON (near Toronto). Integrating my own experiences at this site will help students form an understanding of another, similar problem. Nuisance algal growth can cause a variety of problems, from degrading aesthetics and property values to clogging water intakes and harboring bacteria and pathogens that transmit diseases such as avian botulism. I find it most important to convey to the students why scientists and engineers are studying algae and how it can affect them. Without an understanding of the reason for research on algae, it might be difficult to retain the students' interest. Further, I seek to share details about the problem at the Ajax waterfront and how it is similar and different from *Cladophora* issues in Lake Erie. This will help them understand the complexity of different factors involved, e.g. whole-lake driven versus locally driven algal growth by nutrients.

I think that field, laboratory, and modeling activities are important to help reinforce concepts by providing students real experiences. A field trip on the *Agassiz* would not only be memorable and fun but also show students how scientific field work is done and how samples are obtained for lab analysis. Lab work will teach students a bit about identifying algae and remind them how to use a microscope. Finally, graphing data is important to understand historical and current conditions and using models to explore what-if scenarios teaches students how decisions are made in terms of water quality management related to algae.

Finally – though this is currently not included in this unit summary – I would like to introduce some information on phosphorus regulations and the growing idea of phosphorus bioavailability. Students should be made aware of what scientist already know and have implemented in the past to curb algal blooms. Now the Great Lakes Water Quality Protocol of 2012 demands a new approach to

setting phosphorus loads by involving the concept of bioavailability; i.e. assessments of the percentage of phosphorus in a given load that is available for algal growth should be included in setting limits for phosphorus loads. My lab is currently performing two types of bioassays to determine the bioavailability of particulate and soluble phosphorus. It would be effective to share some of these lab procedures and results with the students, maybe through another unit.