CoSEE MID-ATLANTIC

CENTERS FOR OCEAN SCIENCES EDUCATION EXCELLENCE

EUTROPHICATION

Teacher's Manual

CENTERS FOR OCEAN SCIENCES EDUCATION EXCELLENCE

Preface

The following is a, hands on, and inquiry based lesson plan developed by COSEE Mid-Atlantic for teaching eutrophication. The National Education Science Standards addressed in this lesson plan are: 1) Science as Inquiry; 2) Life Science; 3) Science and Technology; and 4) Science in Personal and Social Perspectives. This lesson plan was intended to satisfy the standards related to grades 5 – 8.

The classroom activities presented in this lesson plan were specifically designed for students in the eighth grade. In this lesson plan, daily activities were developed in the context of 60 minute class periods. In addition, this plan includes enough classroom materials to cover a 5- day school week. ***You are encouraged to add and modify lessons and activities to best meet the needs of your students and the grade level being taught.***

Information regarding reagent refills for the water monitoring kit used in this lesson can be found at: http://www.lamotte.com/pages/edu/pdf/1590-rfb.pdf. For any questions concerning materials presented in the teacher manual or student lab workbook, please feel free to contact:

Erica Holloman
Environmental & Aquatic Animal Health
Virginia Institute of Marine Science
The College of William and Mary
P.O. Box 1346
Gloucester Point, VA 23062
804-684-7256
elhollom@vims.edu

COSEE MID-ATLANTIC
CENTERS FOR OCEAN SCIENCES EDUCATION EXCELLENCE

TABLE OF CONTENTS

INTRODUCTION

National Science Standards Addressed 2

Purpose 2

Objectives 2

Overview 3

CLASSROOM ACTIVITIES

Day 1 9

Day 2 10

Day 3 11

Day 4 12

Day 5 13

APPENDIX

Appendix A 15

Appendix B 18

Appendix C 22

Appendix D 24

Appendix E 26

COSEE MID-ATLANTIC
CENTERS FOR OCEAN SCIENCES EDUCATION EXCELLENCE

INTRODUCTION

COSEE MID-ATLANTIC
CENTERS FOR OCEAN SCIENCES EDUCATION EXCELLENCE

NATIONAL EDUCATION SCIENCE STANDARDS ADDRESSED (5-8th grade):

- Unifying concepts and Processes
  - Evidence, models, and explanation
  - Change, constancy, and measurement

- Science as Inquiry: Content Standard A
  - Abilities necessary to do scientific inquiry

- Life Science: Content Standard C
  - Regulation and Behavior
  - Populations and Ecosystems

- Science and Technology: Content Standard E
  - Understanding about science and technology

- Science in Personal and Social Perspectives: Content Standard F
  - Populations, resources, and environments
  - Natural hazards

PURPOSE:

- To introduce students to the concept of eutrophication.

- To introduce students to the physical and biological factors that influence eutrophication.

- To investigate the process of eutrophication.

OBJECTIVES:

- Students will be expected to make observations.

- Students will learn the physical and biological processes of eutrophication.

- Students will simulate the process of eutrophication.

KEYWORDS:

cultural eutrophication dissolved oxygen, eutrophic, eutrophication, hypereutrophic, light attenuation, loading, mesotrophic, nutrients, nitrogen, non-point source, oligotrophic, phytoplankton, phosphorus, point source, Submerged Aquatic Vegetation (SAV), and water quality parameter.

OVERVIEW:

Eutrophication is the natural ageing process of lakes. This very slow process, which ultimately transforms aquatic environments into terrestrial habitats, begins with the addition of nutrients into the system. These nutrients in turn stimulate the growth of microscopic free-floating aquatic plants known as **phytoplankton** (such as algae). The term eutrophication is also used to describe the human induced process where by human activity such as agriculture, use of fertilizers, and changes in land surrounding aquatic environments accelerates the growth of phytoplankton.

A more accurate term for this process is **cultural eutrophication.** Cultural eutrophication is the accelerated enrichment of surface waters due human activities. Like the natural process of eutrophication, this process results in the excessive growth of phytoplankton caused by the over-enrichment of nutrients.

Nutrients enter aquatic environments as dissolved solutes and compounds bound to organic and inorganic particles. Rivers and streams are mainly responsible for the loading of nutrients to aquatic environments. **Loading** is the amount of nutrients delivered to aquatic environments by way of rivers, streams, or groundwater. Nutrients enter rivers and streams from both point and non point sources. **Point sources** are those from which nutrients are directly being released into the environment. A sewage discharge pipe draining into a river is an example of a point source of nutrients. On the other hand, **non point sources** enter the environment from no specific point. Runoff from an agricultural field that washes into a nearby stream after it rains is an example of a non point source.

Two of the most important nutrients responsible for eutrophication are nitrogen and phosphorus. In freshwater environments (e.g. lakes), phosphorus is usually the nutrient in the lowest concentration and therefore generally limits the growth of phytoplankton. In coastal environments (estuaries), nitrogen usually limits the growth of phytoplankton because it is generally the nutrient in the lowest concentration. **Nitrogen** is commonly found in aquatic environments as nitrate (NO_3^-), nitrite (NO_2^-), or ammonia (NH_4^+ or NH_3). Human factors affecting the concentration of nitrogen in aquatic environments are wastewater and septic system effluent, fertilizer runoff, animal waste, fossil fuel, and industrial discharge. **Phosphorus** is commonly found in aquatic environments as phosphate (PO_4^{-3}). Human factors affecting the concentration of phosphorus in aquatic environments are wastewater and septic system effluent, detergents, fertilizer runoff, animal waste, development/paved surfaces, industrial discharge, phosphate mining, drinking water treatment, forest fires, and synthetic material.

Based on the amount of phytoplankton growth and the concentration of nutrients, the degree of eutrophication in aquatic environments can be classified as oligotrophic, mesotrophic, eutrophic, or hypereutrophic. **Oligotrophic** environments are characterized by clear waters, little suspended organic matter or sediment, and low primary production (phytoplankton growth). **Mesotrophic** environments have higher nutrient inputs and rates of primary production. **Eutrophic** environments have extremely high nutrient concentrations and biological productivity. **Hypereutrophic** environments are characterized by murky, highly productive waters in which many clear water species cannot survive.

The production of harmful algal blooms, low dissolved oxygen concentrations, and changes in species composition are just a few of the effects of eutrophication. Harmful algal blooms are usually produced under eutrophic or hypereutrophic conditions. Cyanobacteria and dinoflagellates are examples of phytoplankton responsible for surface scum, oxygen depletion, and consequent fish kills. Low dissolved oxygen concentrations can result from the decomposition of phytoplankton. As bacteria break down and decompose phytoplankton, they take up dissolved oxygen. Also, the phytoplankton in the bloom consume dissolved oxygen at night. **Dissolved oxygen** is essential to many organisms living in aquatic environments; therefore a decrease in dissolved oxygen concentrations could affect many aquatic organisms. Changes in the abundance and species composition of phytoplankton could change the quality of food available to higher trophic level organisms.

In addition, blooms of phytoplankton can reduce the amount of light available to organisms and plants beneath the surface layer. Submerged aquatic vegetation (**SAV**) can be very sensitive to changes in water clarity. Phytoplankton blooms often make the surface layer very turbid and attenuate light. **Light attenuation** is the decrease in light intensity as a result of absorption of energy and of scattering due to particles (such as phytoplankton) in the water. Severe eutrophication could therefore affect growth of SAV. A decrease in SAV can cause a shift in the species composition due to the important role they play as nursery habitats and refuges for many aquatic organisms.

The management and control of cultural eutrophication is closely related to the prevention and control of pollution. Many state and federal agencies monitor surface and groundwater quality with the goal of preventing severe eutrophication. Dissolved oxygen, pH, nutrients, and chlorophyll a are just a few of the **water quality parameters** that are often monitored. There are many things that as individuals we can do to help prevent human induced eutrophication. Reducing the use of lawn fertilizers and purchasing household detergents and cleaners with low phosphorus concentrations are just two actions that could help control of cultural eutrophication.

CENTERS FOR OCEAN SCIENCES EDUCATION EXCELLENCE

COSEE MID-ATLANTIC

References:

Rast W, and Thornton J., 1996. Trends in eutrophication research and control. Hydrological Processes 10(2), 295-313.

http://www.epa.gov/maia/html/eutroph.html

http://www.unep.or.jp/ietc/Publications/TechPublications/TechPub-12/index.asp

http://bcn.boulder.co.us/basin/data/NUTRIENTS/info/index.html

http://www.umanitoba.ca/institutes/fisheries/eutro.html

CoSEE MID-ATLANTIC
CENTERS FOR OCEAN SCIENCES EDUCATION EXCELLENCE

CLASSROOM

ACTIVITIES

COSEE MID-ATLANTIC
CENTERS FOR OCEAN SCIENCES EDUCATION EXCELLENCE

Day 1
(*Preparation required)

Class Discussion (15 min)
Introduce the concept of eutrophication by engaging students in a discussion to determine what they know about eutrophication. The following questions can be used to guide the discussion.

1. What is eutrophication?
2. What are the physical factors that influence eutrophication?
3. What are the biological factors that influence eutrophication?
4. What are the effects of eutrophication?

Suggestion: Allow students to break into groups to discuss and answer the above questions. Emphasize to students that they should use what they already know about aquatic environments to answer the questions. After the groups have answered the questions, have the groups to present their ideas and answers to the class.

Eutrophication Lecture (30 min)
After the class discussion, spend 30 minutes to teach your eutrophication lecture. You can use the keywords accompanied with this lesson plan to guide your lesson. The following websites can be used to augment one's own understanding of eutrophication:

http://www.umanitoba.ca/institutes/fisheries/eutro.html
http://www-ocean.tamu.edu/~pinckney/Presentations/Eutrophication.pdf
http://water.usgs.gov/nawqa/CIRC-1136.html

Demonstration*(15 min)
Make sure you give yourself at least 3 days (or more) before the demonstration to prepare all of the necessary materials. The demonstration tanks will be used as 1 of the 7 replicates for the experiment so do not discard them at the end of the day.

Materials need
4 small clear plastic 1-liter aquariums
LaMotte /Green Low Cost Water Quality Test Kit
Pond water
Liquid plant fertilizer

Methods
1. Fill each of the aquariums with the pond water and label the tanks 1-4.

CENTERS FOR OCEAN SCIENCES EDUCATION EXCELLENCE

2. Tank 1 is the control tank and no fertilizer is added.
3. In tank 2, add 40 drops of fertilizer and mix well.
4. In tank 3, add 80 drops of fertilizer and mix well.
5. In tank 4, add 120 drops of fertilizer and mix well.
6. Place all four tanks in a location that receives a lot of sunlight.
7. Allow phytoplankton to grow for 3 day.

The morning of the demonstration, test the dissolve oxygen, nitrate, and phosphate for all four tanks. Record the concentrations as follows:

Tanks	Date	D.O	Nitrate	Phosphate
1				
2				
3				
4				

Display the four tanks in the front of the class and write the results from the morning water quality test on the board. Based on what the students already know and from the eutrophication lecture, engage the students in a discussion about the classification of the four tanks. Make sure to include in the discussion the following key words: oligotrophic, mesotrophic, eutrophic, hypereutrophic. After discussion, take a new measurement

Suggestion: Break the students up into groups and have the groups decide the classification of the four tanks. Make sure to emphasis to the students to discuss the reasons as to why they placed the tank in a specific classification. Have the groups present their tank classification to the class.

Day 2

Introduction Discussion (10 min)

Review the concepts on eutrophication from the previous day. Explain to the students that they will be setting up ***microcosms*** to investigate the process of eutrophication. Microcosms are scaled down and simplified versions of a natural environment (e.g. lake or estuary).

Test and record the dissolved oxygen, nitrate, and phosphate concentrations in the demonstration tanks. Have students make observations of the four tanks.

Suggestion: Emphasize any color difference between the tanks. Have students discuss reasons for any differences.

CoSEE MID-ATLANTIC
CENTERS FOR OCEAN SCIENCES EDUCATION EXCELLENCE

Experiment Set-Up (30 min)

Materials needed

25-30 clear plastic 1-liter soda bottles with cap
LaMotte /Green Low Cost Water Quality Test Kit
Pond water
Liquid plant fertilizer

Before class, break your class into six groups with each group containing 5 students or less. Set your classroom up into six different work stations with the following materials at each station:

- *4 clear plastic 1-liter soda bottles with cap*
- *Marker*
- *Copy of methods*

Have students use the following methods to set up the experiment.

Methods

1. Fill each of the aquariums with the pond water and label the tanks 1-4.
2. Test and record the concentration of dissolved oxygen, nitrate, phosphate, and pH.
3. Tank 1 is the control tank and no fertilizer is added.
4. In tank 2, add 40 drops of fertilizer and mix well.
5. In tank 3, add 80 drops of fertilizer and mix well.
6. In tank 4, add 120 drops of fertilizer and mix well.
7. Retest and record the concentration of dissolved oxygen, nitrate, and phosphate.
8. Place all four tanks in a location that receives a lot of sunlight.
9. Allow phytoplankton to grow over the next 3 days

Class Discussion (20 min)

Have each group discuss and develop a hypothesis for the experiment. Emphasize to the students to use what they have learned to predict the results of the experiment. Make sure that each group provides their reasoning behind the development of the group's hypothesis. Next, have each of the groups discuss and identify the sources of nutrients to lakes, ponds, or estuaries. Make sure that the students record the sources of the two nutrients used in the experiment. Have each group present their findings.

Day 3 (*Preparation Required)

Class Discussion (15 min)

CoSEE MID-ATLANTIC
CENTERS FOR OCEAN SCIENCES EDUCATION EXCELLENCE

At the beginning of class, review the concepts on eutrophication and answer any questions that the students may have. Next, allow the groups to measure the concentrations of dissolved oxygen, nitrate, and phosphate in the tanks. Have the students record the information and any observations. *Make sure to continue taking measurements from the demonstration tanks.*

.

Gathering of Presentation Information *(45min)

Make sure that you make the necessary arrangements to have access to the internet for 45 minutes.

Explain to the students that they will use the remainder of the class to gather background information about eutrophication. Information collected should answer the following questions:

- What is eutrophication?
- What are the physical factors that influence eutrophication?
- What are the biological factors that influence eutrophication?
- What are the effects of eutrophication?
- How do federal and state agencies regulate and monitor eutrophication?

Emphasize to the students that the information collected will be used in their final group presentation on Day 5.

Suggestion: Any of the references listed through out this lesson plan can be used to guide the students in their background search.

Day 4 (*Preparation Required)

Class Discussion (10 min)

At the beginning of class, review the concepts on eutrophication and answer any questions that the students may have. Next, allow the groups to measure the final concentrations of dissolved oxygen, nitrate, and phosphate in the tanks. Have the students record the information and any observations. *Make sure to take final measurements from the demonstration tanks.*

Data Analysis/ Presentations Preparation* (50 min)

Make sure that you make the necessary arrangements to have access to computers with internet for 50 minutes.

Allow each of the groups to analyze their data emphasizing how scientific results are presented. The following information should be included in their analysis:

- Tabular representation of results
- Graphic representation of results
- Statement regarding if the hypothesis was rejected
- Conclusions

Next, have the students use the rest of class time to work on their presentations. Presentations should include:

- Background information
- Materials and Methods
- Results
- Conclusions

Suggestion: If computers have Microsoft Excel, have the students use the program to create the necessary tables and graphs. In addition, presentations could be developed using Microsoft PowerPoint.

Day 5 (*Preparation Required)

Class Presentations (50 min)

Allow each group 8 minutes to present their results, allowing 3 minutes for questions.

Suggestion: Have students critique the presentations. Emphasize to the students that their comments should focus on the:

- *Clarity of background information*
- *Clarity of results*
- *Clarity of conclusions.*

Eutrophication Wrap-up Discussion* (10 min):

Prior to class combine all of the results from the experiments (including the demonstration tanks) and analyze them.

Engage your students in a wrap up discussion on eutrophication by presenting the results from the combination of demonstration tank data and the student group data. Emphasize the variability between the tanks and any major observations and comments about the data. Complete the eutrophication lecture by having the students draw final conclusions.

COSEE MID-ATLANTIC

CENTERS FOR OCEAN SCIENCES EDUCATION EXCELLENCE

APPENDIX
A-E

CoSEE MID-ATLANTIC
CENTERS FOR OCEAN SCIENCES EDUCATION EXCELLENCE

Appendix A

The following are data sheets templates that can be used to record all of the data collected during the course of the experiment. This information will assist you in collecting the information needed for the eutrophication wrap-up discussion.

CoSEE MID-ATLANTIC
CENTERS FOR OCEAN SCIENCES
EDUCATION EXCELLENCE

DEMONSTRATION DATA

DAY _________________

Tanks	Date	D.O. (mg/l)	Nitrate (mg/l)	Phosphate (mg/l)
1				
2				
3				
4				

OBSERVATIONS:

COSEE MID-ATLANTIC
CENTERS FOR OCEAN SCIENCES EDUCATION EXCELLENCE

GROUP # _________ DATA

DAY 1				
Tanks	**Date**	**D.O. (mg/l)**	**Nitrate (mg/l)**	**Phosphate (mg/l)**
1				
2				
3				
4				
DAY 2				
Tanks	**Date**	**D.O. (mg/l)**	**Nitrate (mg/l)**	**Phosphate (mg/l)**
1				
2				
3				
4				
DAY 3				
Tanks	**Date**	**D.O. (mg/l)**	**Nitrate (mg/l)**	**Phosphate (mg/l)**
1				
2				
3				
4				

MAJOR OBSERVATIONS:

APPENDIX B

The following rubric was created for the discussion questions found in the student workbook. The discussion questions were purposely not answered to allow flexibility in the information taught. However, they should be used as a basic guide for the information students are expected to know after completion of the daily activities.

COSEE MID-ATLANTIC
CENTERS FOR OCEAN SCIENCES EDUCATION EXCELLENCE

DISCUSSION QUESTIONS RUBRIC:

For each question, 4 is the maximum number of points possible. This gives a total of 60 points possible for all 15 discussion questions.

4 points: The student has a complete and detailed understanding of the ________________ and generates explanations.

3 points: The student has a complete understanding of ______________ .

2 points: The student has an incomplete understanding of ______________ or some misconceptions about ________________ . However, the student has a basic understanding.

1 point: The student has so many misconceptions about ________________ that the the student cannot be said to understand ________________

0 points: Not enough information to make a judgment.

The blanks represent the concepts being asked in the discussion questions.

COSEE MID-ATLANTIC
CENTERS FOR OCEAN SCIENCES EDUCATION EXCELLENCE

DAY 1

DISCUSSION QUESTIONS

1. What is eutrophication?
2. List two physical factors that influence eutrophication?
3. What are the biological factors that influence eutrophication?
4. What are the effects of eutrophication?
5. Name and define the major classifications of eutrophication?

DAY 2

DISCUSSION QUESTIONS:

1. Name at least 3 sources of nitrogen to aquatic environments?
2. Name at least 3 sources of phosphorus to aquatic environments?
3. Explain how dissolved oxygen becomes an issue in a highly eutrophic environment.
4. State the hypothesis developed by your group. Explain the reasoning behind how the group hypothesis was developed.

MID-ATLANTIC

CENTERS FOR OCEAN SCIENCES EDUCATION EXCELLENCE

DAY 3

DISCUSSION QUESTIONS:

1. Explain how urbanization and the population size of a city can influence eutrophication?
2. How do federal and state agencies regulate and monitor eutrophication?
3. Explain how dissolved oxygen becomes an issue in a highly eutrophic environment?

DAY 4

DISCUSSION QUESTIONS:

1. What was the mean concentration of nitrate (NO_3^-) in all four tanks?
2. What was the mean concentration of phosphate (PO_4^{-3}) in all four tanks?
3. Explain the relationship between your observations and results during the course of the experiment. Use the following key words in your explanation**: dissolved oxygen, eutrophic, eutrophication, hypereutrophic, light attenuation, mesotrophic, nutrients, nitrogen, oligotrophic, phytoplankton, and phosphorus.**

CoSEE MID-ATLANTIC
CENTERS FOR OCEAN SCIENCES EDUCATION EXCELLENCE

APPENDIX C

The following rubric was developed to critique the group presentations. This rubric is also included in the student workbook.

CENTERS FOR OCEAN SCIENCES EDUCATION EXCELLENCE

PRESENTATION RUBRIC:

This rubric is based on six key scientific presentation skills necessary to disseminate results and conclusions from observations and experiments. For each skill, 5 is the maximum number of points possible. This gives a total of 30 points possible for the group presentation.

5 points: Excellent

4 points: Good

3 points: Fair

2 point: Poor

1 point: Not enough information to make a judgment.

GROUP # ____________________

	1	**2**	**3**	**4**	**5**
Clarity of background information					
Clarity of Methods					
Hypothesis was clearly stated					
Clarity of results					
Conclusions clearly stated					
Overall Presentation					
TOTAL					

COMMENTS:

APPENDIX D

The following rubric was developed to critique the student lab workbook. This rubric is also included in the student workbook.

CoSEE MID-ATLANTIC
CENTERS FOR OCEAN SCIENCES EDUCATION EXCELLENCE

STUDENT LAB WORKBOOK RUBRIC:

The maximum points possible using this rubric is 10. Each category is based on the sections expected to be completed in the student lab workbook.

2 points: Excellent

1 point: Fair

0 points: Not enough information to make a judgment.

	0	**1**	**2**
Data worksheets complete			
Observations clearly stated			
Hypothesis was clearly stated			
Data Analysis			
Conclusions clearly stated			
TOTAL			

COMMENTS:

APPENDIX E

The following is a final grade template that breaks down the total points possible for this lesson plan. Points are based on the rubrics used to assess the discussion questions, group presentations, and student lab workbooks.

COSEE MID-ATLANTIC
CENTERS FOR OCEAN SCIENCES EDUCATION EXCELLENCE

EUTROPHICATION FINAL GRADE POINT BREAKDOWN

	Total points earned	Total points possible
DISCUSSION QUESTIONS		**60**
GROUP PRESENTATION		**30**
STUDENT LAB WORKBOOK		**10**
TOTAL		**100**

COMMENTS:

COSEE MID-ATLANTIC

CENTERS FOR OCEAN SCIENCES EDUCATION EXCELLENCE

EUTROPHICATION SCIENCE KIT

Please check to make sure that your Eutrophication Science Kit is complete.

<u>MATERIALS INCLUDED IN KIT:</u>

	Quantity
Eutrophication Science Kit CD	**1**
Teacher's Manual	**1**
LaMotte/Green Low Cost Water Monitoring Kit	**1**
Lee's Kritter Keeper (with lids)	**4**
Large Clear Plastic Centrifuge Tubes (without cap)*	**24**
Small Clear Plastic Centrifuge Tubes (with cap)*	**12**

<u>MATERIALS NOT INCLUDED IN KIT (but required):</u>

Clear Plastic 1-liter soda bottles (6)

Liquid Plant Fertilizer (ex., Miracle-Gro® Liquid All Purpose Houseplant Food)

Extra Reagent Refills**

** A special thanks to Dr. Kam Tang and the Plantonic and Microbial Processes Laboratory at the Virginia Institute of Marine Science (VIMS) for donating the centrifuge tubes.*

*** Information for ordering reagent refills fro the water monitoring kit used in this lesson can be found at: http://www.lamotte.com/pages/edu/pdf/1590-rfb.pdf*