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ABSTRACT

This teacher guide and student workbook set presents two learning activities, designed for fifth through ninth grade students, that concentrate on nutrients in the Great Lakes. In activity A, students simulate aquatic habitats using lake water and goldfish in glass jars and observe the effects of nutrient loading and nutrient limitation on aquatic life. In Activity B, students graph phosphate and nitrate inputs to Lake Erie following a storm. As prerequisite to these activities, students should know how to use a microscope, be able to draw line graphs, and be familiar with the concept of nutrients. When students have completed these activities, they should be able to: (1) describe the characteristics of oligotrophic and eutrophic lakes, (2) explain the effects of nutrient loading on lake habitats, (3) define nutrients as a limiting factor in lake habitats, (4) list sources of nutrient inputs to Lake Erie, and (5) explain how wetlands can improve water quality. The teachers guide includes additional information to aid in processing the activities. Extension activities are provided along with suggested references, review questions and student worksheets. (MCO)

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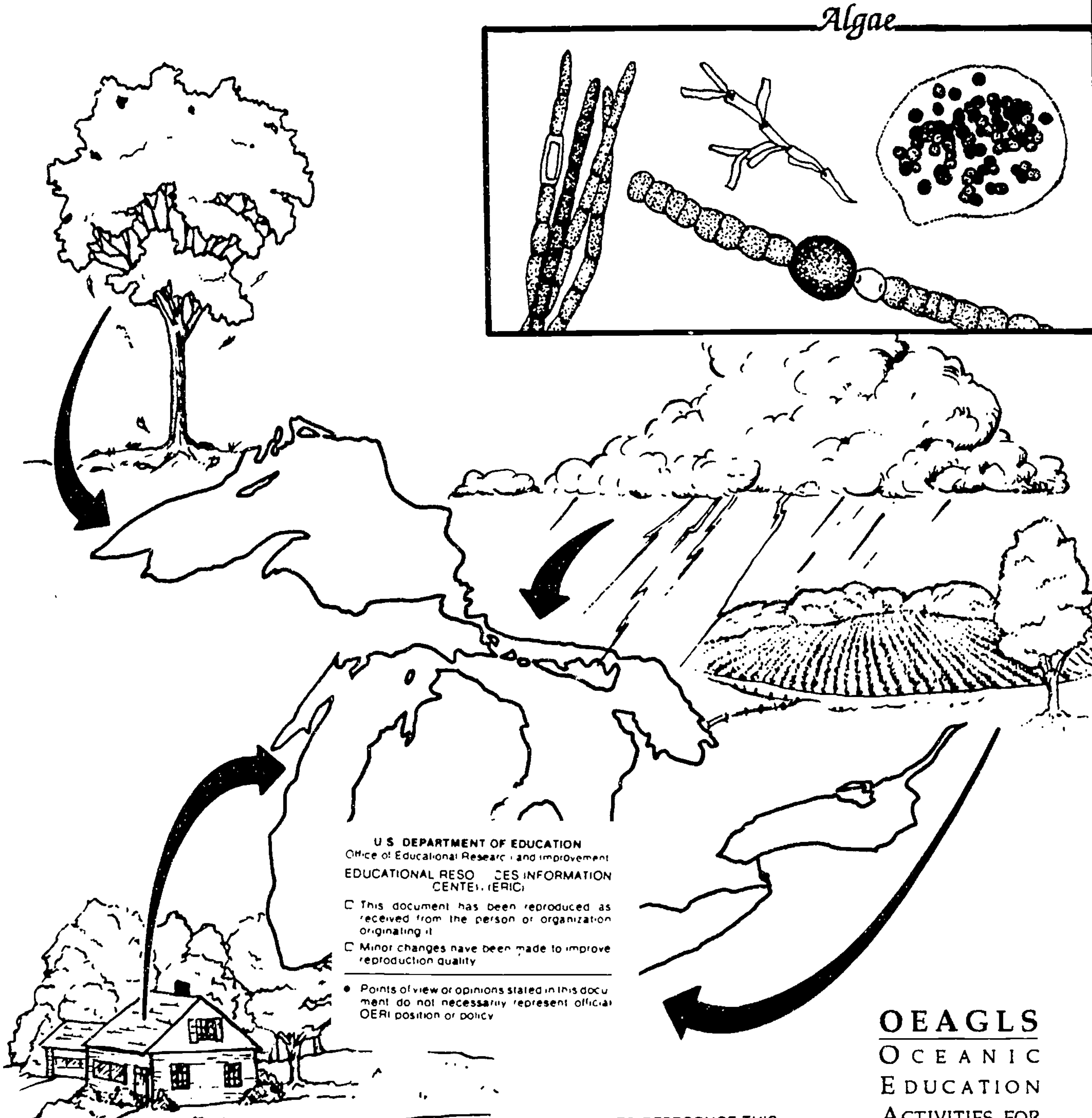
OHIO SEA GRANT COLLEGE PROGRAM

Nutrients in the Great Lakes

Chris Brothers, David A. Culver, & Rosanne W. Fortner

The Ohio State University



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OCEANIC EDUCATION ACTIVITIES FOR GREAT LAKES SCHOOLS

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TEACHER GUIDE

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OEAGLS EP-029T
Teacher Guide
Completed December 1991

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Activity A was adapted from David A. Culver's, "Nitrogen, Phosphorus and Algal Growth: The Goldfish Culture," *Life Science Teachers Program Module*. OSU College of Biological Sciences.

Activity B is based on David Klarer's, "The Role of a Freshwater Estuary in Mitigating Storm Water Inflow." Old Woman Creek Technical Report #5, March 1988.

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NUTRIENTS IN THE GREAT LAKES (EP-029T)

Teacher Guide*

OHIO SEA GRANT COLLEGE PROGRAM

Chris Brothers, David A. Culver, and Rosanne W. Fortner
The Ohio State University

Overview:
In Activity A, students simulate aquatic habitats using lake water and goldfish in glass jars and observe the effects of nutrient loading and nutrient limitation on aquatic life. In Activity B, students graph phosphate and nitrate inputs to Lake Erie following a storm.

Prerequisite Student Background:
Students should know how to use a microscope and be able to draw line graphs. They should be familiar with the concept of nutrients.

Objectives:
When students have completed these activities, they should be able to:

1. describe the characteristics of oligotrophic and eutrophic lakes,
2. explain the effects of nutrient loading on lake habitats,
3. define nutrients as a limiting factor in lake habitats,
4. list sources of nutrient inputs to Lake Erie, and
5. explain how wetlands can improve water quality.

Materials:
Activity A: (For the entire class)—Three 1 quart glass jars, masking tape for labels, 1 to 2 gallons of recently gathered pond or lake water, stereo and/or standard microscopes, pond life identification guides, two goldfish, fish food flakes, and an incandescent light. If you have enough supplies, you may want to have small groups of students each prepare and observe a set of jars. **Activity B:** nitrate and phosphate data charts, map of Old Woman Creek, graph paper, pencils, glass jar with lid, and soil.

Suggested Approach:
Activity A: This will involve approximately one week of observation time during which students will record data about changes occurring in the simulation jars. Some changes will be visible to the eye. To observe others, microscopes can be used. Discuss the changes occurring as they become evident. The pond water used for this activity must contain active aquatic organisms, both plant and animal. This can be checked using a microscope. You may want to collect the water with your students. The water should be filtered before the activity using a plankton net. If you do not have a plankton net, you can make one by epoxying a small piece of silkscreen fabric over one end of a round plastic tube, such as a PVC pipe. Silkscreen fabric is available at some art stores or you may be able to get scraps from a t-shirt printing store. **Activity B:** Students can work on this activity as individuals or in small groups. The graphing section of the activity and the worksheet could also be conducted as a homework assignment. The activity should take approximately 45 minutes.

***Note:** Information to teachers is enclosed in boxes in this guide.

OHIO SEA GRANT COLLEGE PROGRAM

NUTRIENTS IN THE GREAT LAKES (EP-029T)
Teacher Guide

Chris Brothers, David A. Culver, and Rosanne W. Fortner
The Ohio State University

Introduction:

Well-meaning people in the 1970's claimed that Lake Erie was dead or at least dying. That impression came from the visible conditions: dead fish on the shore, lots of algae washing up and creating odors, and beaches that were unfit for swimming. Things didn't look very lively!

However, Lake Erie was never dead. In fact, its problems came from too much life! When fertilizers used on farms ran off into the lake, the lake was fertilized too. The sewage from cities near the lake had lots of phosphates in it from detergents and human waste, and the sewage also acted as a fertilizer. The sewage and farm fertilizers supplied two nutrients—phosphorus and nitrogen (in the form of phosphates and nitrates)—to the lakes. These are mineral nutrients that algae and other plants need to grow. The result was that the plants in the lake responded just as plants on land respond to fertilizer—they grew and grew. Huge algae blooms quickly used up nutrients and were followed by great algae die-offs, changing the ecology of the lake. As the algae died, the decay process used up all the oxygen in some parts of the lake. When all the oxygen was gone, fish and other animals could no longer live in these parts of the lake.

Scientists call the aging process of a lake **eutrophication**. Natural eutrophication results as nutrients enter the lake and cause increased plant growth. Water drainage running off from the surrounding land into the lake, sediments from the bottom of the lake, and the living and dead plants and animals within the lake are natural sources of nutrients. Natural eutrophication is a slow process. People aged Lake Erie in a different way by over-fertilizing it with added nutrients. When human activity speeds eutrophication by overloading the lake with nutrients, the process is called **cultural eutrophication**.

Objectives:

When students have completed these activities, they should be able to:

1. describe the characteristics of oligotrophic and eutrophic lakes,
2. explain the effects of nutrient loading on lake habitats,
3. define nutrients as a limiting factor in lake habitats,
4. list sources of nutrient inputs to Lake Erie, and
5. explain how wetlands can improve water quality.

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Activity A: What happens when nutrients enter a lake?

Lakes that are low in nutrients are called **oligotrophic**. These lakes have low plant production and very clear water. They are often very deep and have a small surface area. Because they are so deep, wind and waves do not mix the water enough to stir nutrients throughout the lake. Sunlight does not reach the deep parts, either. Lake Superior is an example of an oligotrophic lake.

Lakes rich in nutrients are called **eutrophic**. Eutrophic lakes produce abundant plant life and have murky water. They are often shallow and have a large surface area. Because they are shallow, the water in these lakes is easily mixed by wind and waves, making nutrients available throughout the lake. Lake Erie is an example of a eutrophic lake.

What changes occur in the plant and animal life of a lake when nutrients enter the water? What happens if there are not enough of some nutrients in the lake?

Materials:

Three 1 quart glass jars, masking tape for labels, 1 to 2 gallons of recently gathered pond or lake water, stereo and/or standard microscopes, pond life identification guides, two goldfish, fish food flakes, and an incandescent light.

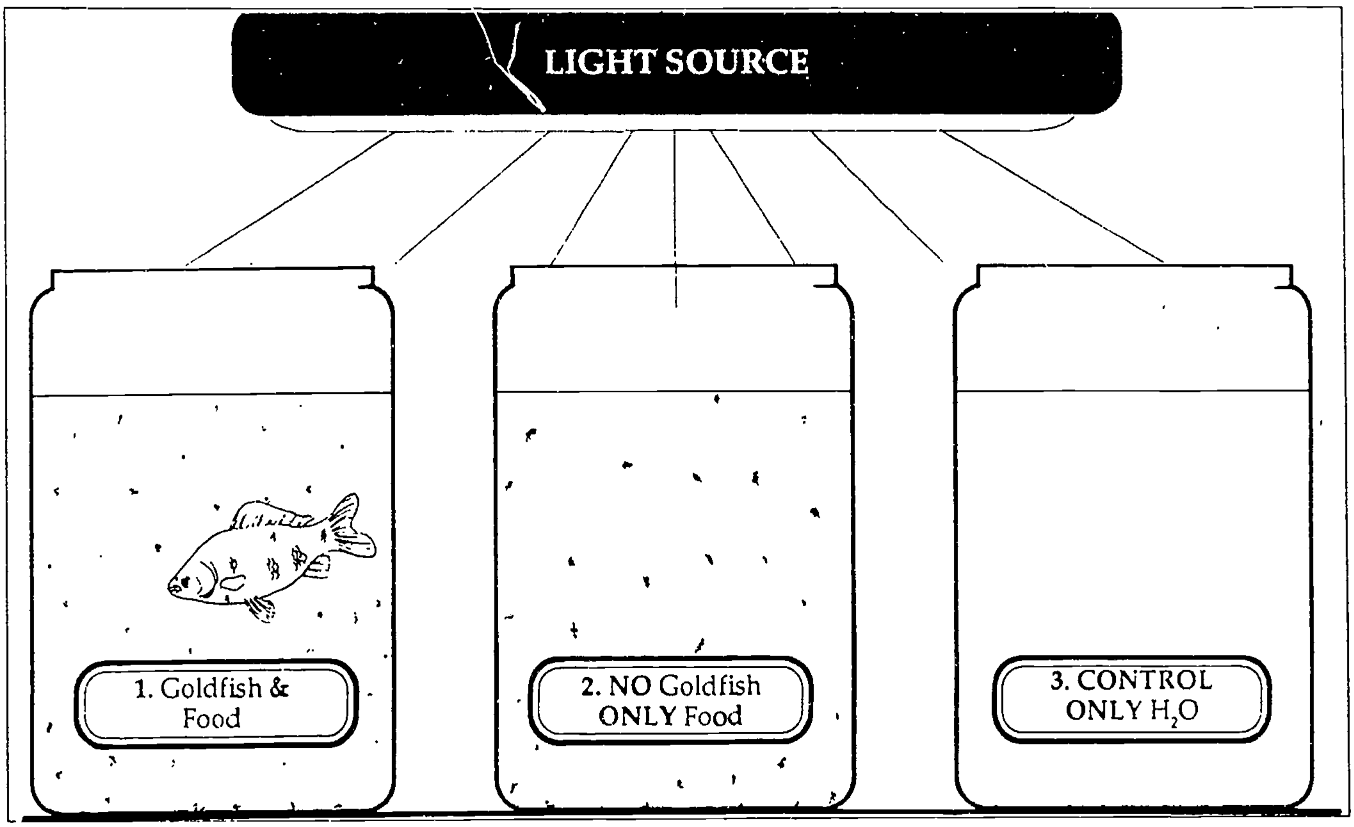
Procedure:

A. Label the three 1 quart jars as follows:
   1. Goldfish—feed daily
   2. Invisible Goldfish—feed daily
   3. Control—do not feed

B. Prepare each of the jars as follows:
   1. Goldfish—Fill the jar with lake water and add the two goldfish. Feed these goldfish every day with a pinch of fish food flakes.
   2. Invisible Goldfish—Fill the jar with lake water. Sprinkle each day with a pinch of fish food flakes. This jar should not contain goldfish.
   3. Control—Fill the jar with lake water. Do not put any goldfish or fish food in this jar.

C. If possible, add an aquarium bubbler to these three jars to add oxygen to the water. Set the jars aside in a visible and safe place. Place an incandescent light such as a gooseneck lamp above each jar. Leave the light on 24 hours a day.

D. Using the microscopes, look at some of the remaining lake water. Record your observations. You may want to draw some of the plants and animals you see and look them up in a guide to pond or lake life.

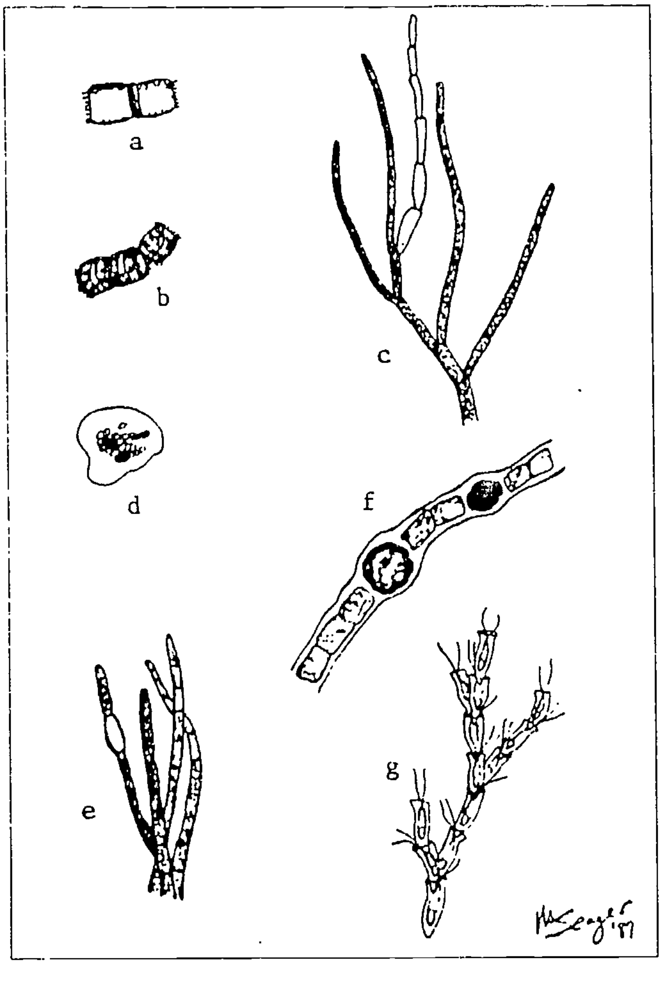


E. Each day during the observation period, check the jars for any changes. Record your observations. Some changes will be visible to the eye. You may also want to look at some of the water life with a microscope. Be sure to feed your goldfish every day.

In your lake water you are likely to see green and blue-green algae. Both kinds of algae need the nutrients phosphorus and nitrogen in order to grow. If there is not enough of these nutrients for algae to grow, these nutrients are said to be *limiting*: the lack of these nutrients limits or prevents algae from growing.

The pictures below show species of algae living in Lake Erie. Some may appear in your jars.

Pollution tolerant green algae:
a) *Melosira* b) *Stephanodiscus* c) *Cladophora*
Pollution tolerant blue-green algae:
d) *Microcystis* e) *Aphanizomenon* f) *Anabaena*
Pollution intolerant form:
g) *Dinobryon*



Biologists now classify blue-green as cyanobacteria. They do not have a nucleus like other algal cells. The term algae is used here to prevent confusion among younger students.

1. In jar #1, what is the source of nutrients entering the water? Where are nutrients coming from in jar #2? Are there any nutrients entering jar #3?

In jar #1, nutrients are entering the water from the fish food flakes and from the fish themselves as they produce wastes. In jar #2, nutrients are coming from the fish food only. No nutrients are entering jar #3, the control jar. All three jars have the bubbler, if available, as a supply of oxygen, so differences in algae growth in the three jars are not likely to be the result of oxygen differences.

2. Which jar do you think will show the most algal growth? Which will show the least algal growth?

Jar #1 will likely show the most algal growth because the fish are a source of nutrients in addition to the fish food. The fish also speed up the decomposition of the food. The control jar #3 will likely show the least growth. The growth in jar #2 will depend on the nutrient content of the fish food.

If both phosphorus and nitrogen are available in the water, the green algae will out compete the blue-green algae, meaning more green algae will grow than blue-green algae.

3. In which jar has more green algae grown than blue-green algae?

This will likely happen in jar #1 as the fishes wastes are providing nitrogen. Neither nitrogen or phosphorus is limiting.

Both green and blue-green algae will grow until all the nitrogen in the water is used up. The green algae will then stop growing. The nitrogen will have become the limiting nutrient for the green algae. The blue-green algae can keep growing after the nitrogen in the water is used up, because the blue-green algae can use nitrogen from the air. Thus, when nitrogen is limiting, the blue-green algae will out-compete the green algae, meaning more blue-green algae will grow than green algae.

4. In which jar is blue-green algae growing better?

Blue-green algae will likely grow better in jar #2 when nitrogen is limiting but phosphorus is still available. The blue-green algae will keep growing until all the phosphorus in the water is used up. When the phosphorus is gone, it becomes the nutrient limiting algal growth.

5. What nutrient is limiting in jar #2? What nutrient do you think might become limiting in jar #1 (hint: the fish produces nitrogen in its wastes)? What nutrient appears to be limiting in the control jar (#3)?

Nitrogen is likely limiting in jar #2 because its only source is the fish food. It can be used up rapidly. Phosphorus may become limiting in jar #1 as nitrogen is available through both the fish food and the fishes wastes. Either may be limiting in jar #3. Which nutrient is limiting will depend on the original supply of nitrogen and phosphorus in the lake water and on the nutrient content of the fish food.

If you feel the concept of which nutrient is limiting in which jar is too difficult for your students, you may just want to emphasize the idea that the algae in the jars need nutrients to grow and that with more nutrients, more algae grows. Students should be able to see more algae growing in some jars than in others.

Nitrate and Phosphate Data Chart

		DAY AFTER STORM (May 1985)										
Station	**Nutrient**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1	P (ppb)	283	82	70	94	60	32	40	49	40	35	30
	N (ppm)	6.5	6.9	9.7	12.4	10.5	9.5	7.8	6.5	6.6	6.5	6.6
2	P	104	97	79	79	50	35	21	12	10	7	3
	N	1.5	3.3	6.1	8.7	9.0	10.1	9.0	8.0	7.7	6.5	5.9
3	P	9	41	67	66	32	19	15	10	9	8	7
	N	.4	1.9	2.8	7.6	8.4	9.9	8.0	6.8	5.8	4.1	2.3
4	P	9	7	35	28	19	11	11	10	7	5	3
	N	.2	.3	2.4	3.3	5.1	8.8	8.7	8.4	6.5	4.8	2.2
5	P	8	11	10	22	20	16	12	10	6	3	2
	N	.2	.8	.6	2.6	4.9	9.7	7.8	6.9	6.0	4.1	2.3
6	P	9	5	10	26	19	11	10	10	8	6	5
	N	.5	.5	2.0	3.4	3.4	3.4	3.3	3.3	3.0	2.7	1.7
7	P	5	2	1	6	5	3	3	3	2	2	2
	N	.9	1.0	1.1	1.4	1.6	1.7	2.0	2.1	1.7	1.5	1.2

(Data for underlined dates were interpolated from those before and after the date. P and N were not measured directly on these days.)

Activity B: How do nutrients enter the Great Lakes?

How do phosphorus and nitrogen get into the Great Lakes? One way is from water runoff. Rainwater falling on farm fields, parking lots, roads, and backyards flows into creeks, streams, and rivers. The rainwater carries soil, fertilizers, and other pollutants it has washed from the land. You have probably seen how much more water creeks carry just after a storm and how muddy the water looks. Eventually, all this water runs into the lakes, bringing nutrients and other chemicals with it.

Materials:

Nitrate and Phosphate Data Chart, map of Old Woman Creek, graph paper, pencils, glass jar with lid, and soil.

Procedure:

A. Look at the map of Old Woman Creek. With your pencil, trace the path of the creek starting at the point marked A.

1. Where does the creek go? Does water from the creek flow into Lake Erie?

The creek flows north into Old Woman Creek Estuary and then empties into Lake Erie.

B. On the same map, look at the land that is surrounded by the dotted line. All the land within this line is the watershed of Old Woman Creek. A **watershed** is all of the land drained by a creek, stream, or river. Water from this land runs off into Old Woman Creek, then through Old Woman Creek Estuary before reaching Lake Erie.

2. Are there any roads or farms in the Old Woman Creek watershed? How might these affect the water entering the creek?

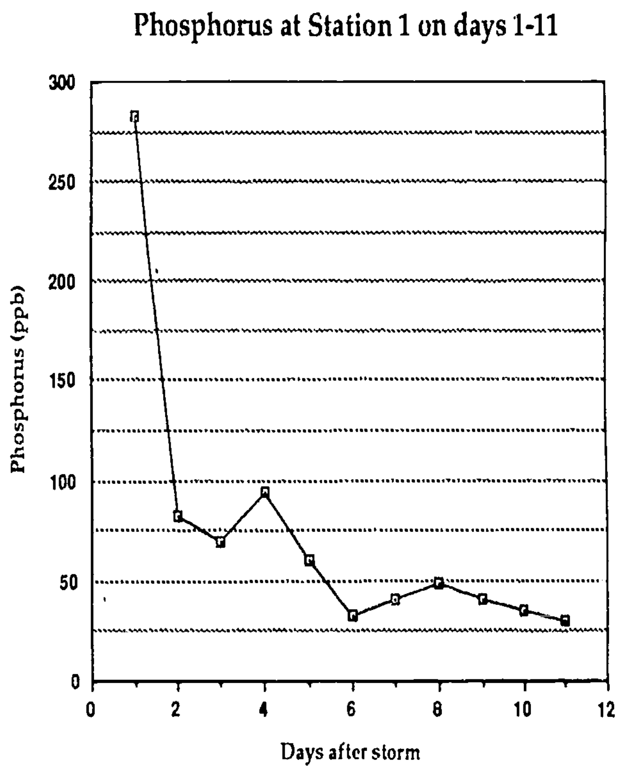
U.S. Highway 6 and Ohio Routes 2 and 61 run through the watershed. There are also several farms. Runoff water from roads and farms will carry fertilizers and other pollutants.

C. The map also shows places in the estuary where scientists have tested the creek's water to see how much phosphorus and nitrogen it contains.

3. How many test stations are located in the estuary? Which station is closest to the lake? Which is closest to where the creek enters the estuary?

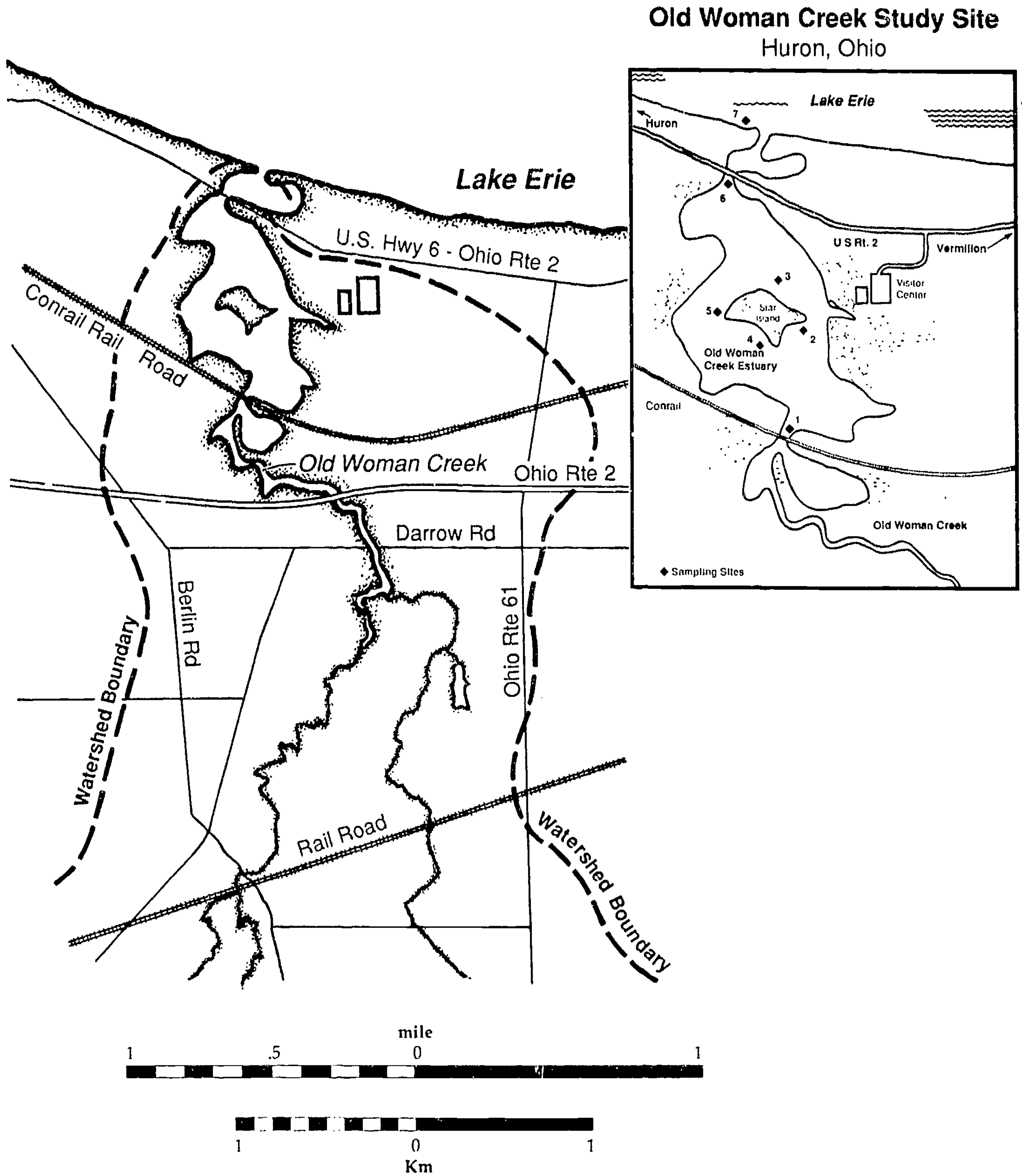
There are seven water test stations in the estuary. Station 7 is closest to the lake. Station 1 is closest to where the creek enters the estuary.

D. On a piece of graph paper, graph the concentration of phosphorus at Station 1 in the estuary for each day after the storm from day 1 to day 11. Use the data from the Nitrate and Phosphate Data Chart.

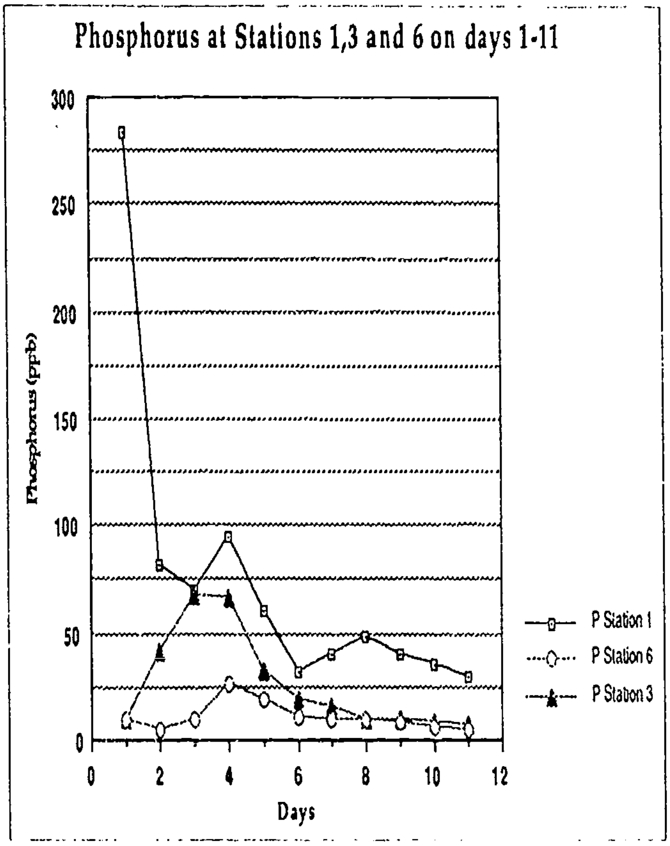


4. At Station 1, how many days after the storm were phosphorus levels the highest? When were phosphorus levels the lowest? How can you explain this?

Phosphorus levels were highest one day after the storm and lowest 11 days after the storm. One day after the storm, a lot of runoff water from the storm was entering the estuary. This water contained high concentrations of phosphorus. By day 11, much less runoff from the storm was entering the estuary. Thus, fewer nutrients were being carried into the estuary.



Map of the lower end of the Old Woman Creek watershed.



E. Now graph phosphorus concentrations at Stations 3 and 6 for each day after the storm. If you use the same sheet of graph paper to draw this graph, be sure to label your lines Station 1, Station 3, and Station 6.

5. What day did peak (highest) phosphorus concentrations occur at Station 3? What day did phosphorus peak at Station 6? Can you explain why peak concentrations of phosphorus occurred later at Station 3 than at Station 1 and later at Station 6 than at Station 3?

Stations 3 and 6 are located further downstream in the creek. Water from the creek reaches Station 1 first, then Station 3, then Station 6. Nutrients such as phosphorus being carried by the water reach these stations in the same order.

F. Look at the data showing nitrogen concentrations at Stations 1, 3, and 7.

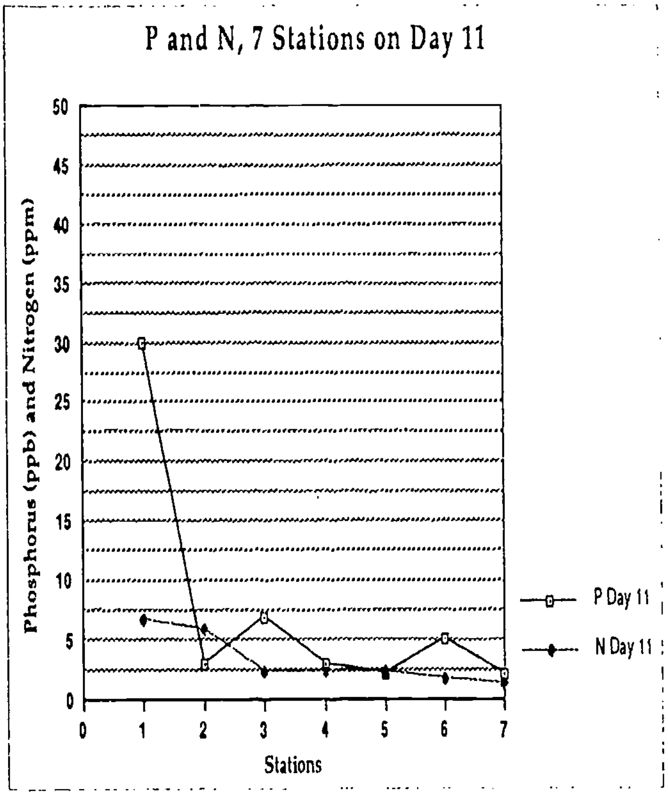
6. On what day do the peak concentrations of nitrogen occur at each station? Does it seem that the peak nitrogen concentrations are following the same kind of pattern that peak phosphorus concentrations showed?

Peak nitrogen concentration at Station 1 occurs on day 1, at Station 3 on day 6, and at Station 7 on day 8. Nitrogen concentrations are following the same general pattern as phosphorus concentrations. The peak concentration of nitrogen at stations further downstream occurs after it does at upstream stations.

7. By day 9, has the peak in phosphorus and nitrogen concentrations occurred at all seven stations?

By day 9 the peak in phosphorus and nitrogen concentrations has occurred at each of the stations.

G. On a new sheet of graph paper, make a graph of the concentration of phosphorus at each station in the estuary on day 11.



8. For day 11, at which station are phosphorus concentrations the highest? At which station are they the lowest?

Phosphorus concentrations on day 11 are highest at Station 1 and lowest at Station 5 and 7.

H. On the same graph paper you used in step G, graph the concentration of nitrogen at each station in the estuary on day 11. (Note that N and P are not measured in the same units. This is consistent with the data.)

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9. At which station are nitrogen concentrations the highest? At which station are they the lowest?

Nitrogen concentrations are the highest at Station 1 and the lowest at Station 7. Nitrogen and phosphorus can be either dissolved in the water, suspended as particles, or attached to sediments.

I. Fill a jar half full of water. Put a handful of soil into the jar. Shake the jar so that the water and soil are moving quickly and get mixed together. You have created muddy, stirred-up creek water in your jar. Wait a few minutes for the water to slow down and the soil to settle to the bottom of the jar. The water in the jar now is more like water in the estuary.

10. Where do you think estuary water will be the muddiest? Where will it be the clearest? What is one reason why phosphorus and nitrogen concentrations are lower at Station 7 than at Station 1?

Following a storm, creek water is muddy from carrying soil and nutrients, and it is moving very quickly. As water flows through the estuary, its movement is slowed. Much of the sediment, soil, and nutrients in the water settles out as the water slows down. Thus, the water reaching downstream stations is clearer and has lower concentrations of nutrients than the water flowing through the upstream stations.

11. The estuary has many plants growing in it. How might the plants affect the amount of nutrients reaching each station?

To explain the decrease in the phosphorus and nitrogen concentrations from Station 1 to Station 7, try the following. Plants in the estuary need phosphorus and nitrogen to grow. Thus, plants in the estuary take up and use phosphorus and nitrogen from the creek water as it passes through the estuary. The plants filter out the nutrients that they need from the creek water. This is another reason that fewer nutrients reach the downstream stations.

Estuaries and other wetlands act as "sinks" and "sponges" for nutrients. Nutrients associated with mud settle out of the creek water and sink to the bottom of the estuary as the water passes slowly through the estuary. At the same time, nutrients are taken up by estuary plants.

12. How might an estuary's action as a "sink" and "sponge" for nutrients affect the lake into which the creek empties?

Because of the estuary's filtering action, water entering the lake will contain fewer nutrients than it otherwise would. Many of Lake Erie's water problems result from too many nutrients entering the lake. Estuaries may improve water quality in the lake by reducing the nutrients entering it.

Ideas for Extension:

1. *Lake Layers: Stratification*, OEAGLS activity number EP-028, includes two activities related to nutrients in the lakes and water quality. Students use an aquarium to simulate the stratification of water that occurs in lakes during the summer. On several maps of Lake Erie, they measure the area that has become anoxic (lacking oxygen) since the 1930s and relate this to nutrient inputs.
2. *The Estuary: A Special Place*, OEAGLS activity number EP-016, includes activities designed for further investigation of the Old Woman Creek Estuary. Students study the characteristics of an estuary using a computer map and a transect line, then analyze illustrations of plankton samples to observe how estuaries serve as nurseries for lake fish.

Review Questions:

1. What are the characteristics of oligotrophic and eutrophic lakes?

Oligotrophic lakes have low nutrient levels. They are often deep and have small surface areas. Plant production is low and the water is clear. Eutrophic lakes are rich in nutrients. They are often shallow and have large surface areas. Plant production is high and the water is murky.

2. What happens when nutrients are readily available in, or are added to, a lake?

The nutrients act as a fertilizer allowing plants to grow. Adding nutrients increases plant growth, especially the growth of algae. The algae may be green or blue-green depending on what nutrients are available.

3. What is a limiting nutrient? What nutrients are usually limiting for algal growth in a lake?

Nutrients are needed for plant growth. The nutrient that is a missing or available only in low levels is the limiting nutrient because it limits or controls the amount of plant growth. Phosphorus and nitrogen are usually the limiting nutrients in lakes. These are often in the form of PO_4^{-3} (phosphate) and NO_3^{-1} (nitrate) ions.

4. What are some of the human-produced sources of nutrients entering the lakes?

Nutrients enter the lake in run-off from farms, parking lots, roads, and yards. This runoff contains soil, fertilizers, and other pollutants it has carried from the land. Sewage can also contain nutrients from detergents with phosphates and from human waste.

5. How do estuaries act as "sinks" and "sponges", improving the quality of the water going through them to the lake?

Plants in the estuary take up and use the nutrients they need from the water passing through the estuary, thus acting as sponges. As water flows through the estuary, its movement is slowed. Much of the soil and nutrients in the water settle out as it slows down. Thus, the wetlands act as nutrient sinks. Estuaries may improve the water quality of the lake by reducing the amount of nutrients entering the lake.

Suggested References

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OHIO SEA GRANT COLLEGE PROGRAM

Nutrients in the Great Lakes (EP-029T)

Answer Sheet

NAME

Activity A: What happens when nutrients enter a lake?

1. In jar #1, what is the source of nutrients entering the water? ______

   Where are nutrients coming from in jar #2? ______

   Are there any nutrients entering jar #3? ______

2. Which jar do you think will show the most algal growth? ______

   Which will show the least algal growth? ______

Use an extra page to record changes you see in each of the jars during the observation period.

3. In which jar has more green algae grown than blue-green algae? ______

4. In which jar is blue-green algae growing better than green algae? ______

5. What nutrient is limiting in jar #2? ______

   What nutrient do you think might become limiting in jar #1? ______

   What nutrient appears to be limiting in the control jar (#3)? ______

Activity B: How do nutrients enter a lake?

1. Where does the creek go? ______

   Does water from the creek flow into Lake Erie? ______

2. Are there any roads or farms in the Old Woman Creek watershed? ______

   How might these affect the water entering the creek? ______

   ______

3. How many test stations are located in the estuary? ______

   Which station is closest to the lake? ______

   Which is closest to where the creek enters the estuary? ______

4. At Station 1, how many days after the storm were phosphorus levels the highest? ______

   When were phosphorus levels the lowest? ______

ERIC

How can you explain this? ______________________________

____

5. What day did peak (highest) phosphorus concentrations occur at Station 3? ______________

What day did phosphorus peak at Station 6? ______________________________

Can you explain why peak concentrations of phosphorus occurred later at Station 3 than at Station 1, and later at Station 6 than at Station 3? ______________________________

____

6. On what day do the peak concentrations of nitrogen occur at Stations 2, 3, and 7?

____

Does it seem that peak nitrogen concentrations are following the same kind of pattern that peak phosphorus concentrations showed? ______________________________

7. By day 9, has the peak in phosphorus and nitrogen concentration occurred at all seven stations? ___

____

8. For day 9, at which station are phosphorus concentrations the highest? ______________

At which station are they the lowest? ______________________________

9. At which station are nitrogen concentrations the highest? ______________________________

At which station are they the lowest? ______________________________

10. How can you explain the decrease in phosphorus and nitrogen concentrations from Station 1 to Station 7? ______________________________

____

11. Where do you think estuary water will be the muddiest? Where will it be the clearest? ______________

____

What is another reason why phosphorus and nitrogen concentrations are lower at Station 7 than at Station 1? ______________________________

12. How might an estuary's action as a "sink" and "sponge" for nutrients affect the lake into which the creek empties? ______________________________

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THE OHIO STATE UNIVERSITY

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Dr. Jeffrey M. Reutter, Ohio Sea Grant Director

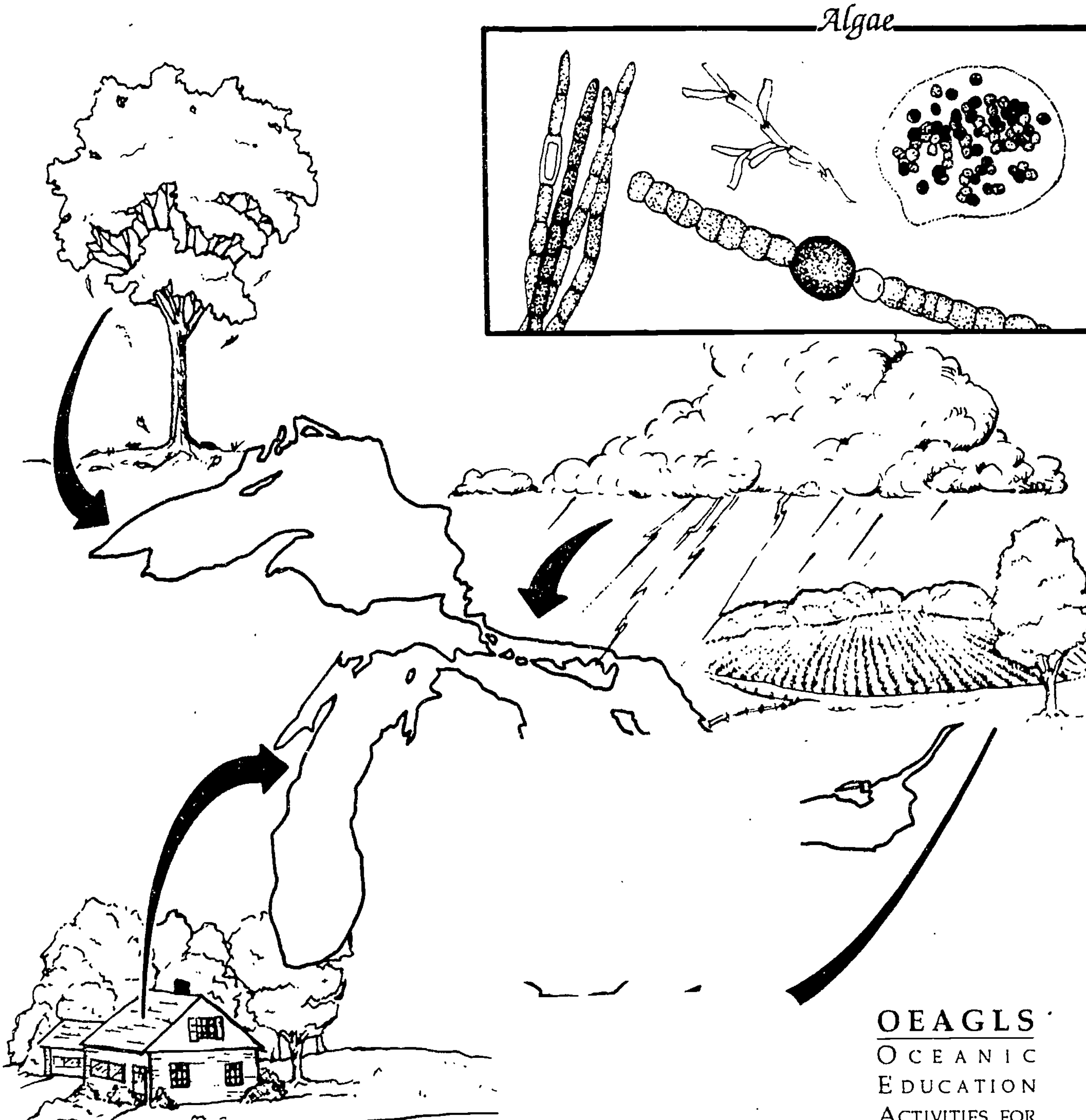
EP-029S

Nutrients in the Great Lakes

Chris Brothers, David A. Culver, & Rosanne W. Fortner

The Ohio State University

OHIO SEA GRANT COLLEGE PROGRAM



STUDENT GUIDE

OEAGLS
OCEANIC EDUCATION ACTIVITIES FOR GREAT LAKES SCHOOLS

Ohio Sea Grant College Program

OEAGLS EP-029S
Student Workbook
Completed December 1991

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Activity A was adapted from David A. Culver's, "Nitrogen, Phosphorus and Algal Growth: The Goldfish Culture," *Life Science Teachers Program Module*. OSU College of Biological Sciences.

Activity B is based on David Klarer's, "The Role of a Freshwater Estuary in Mitigating Storm Water Inflow." Old Woman Creek Technical Report #5, March 1988.

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OHIO SEA GRANT COLLEGE PROGRAM

NUTRIENTS IN THE GREAT LAKES (EP-029S)

Student Workbook

Chris Brothers, David A. Culver, and Rosanne W. Fortner
The Ohio State University

Introduction:

Well-meaning people in the 1970s claimed that Lake Erie was dead or at least dying. That impression came from the visible conditions: dead fish on the shore, lots of algae washing up and creating odors, and beaches that were unfit for swimming. Things didn't look very lively!

However, Lake Erie was never dead. In fact, its problems came from too much life! When fertilizers used on farms ran off into the lake, the lake was fertilized too. The sewage from cities near the lake had lots of phosphates in it from detergents and human waste, and the sewage also acted as a fertilizer. The sewage and farm fertilizers supplied two nutrients—phosphorus and nitrogen (in the form of phosphates and nitrates) — to the lakes. These are mineral nutrients that algae and other plants need to grow. The result was that the plants in the lake responded just as plants on land respond to fertilizer — they grew and grew. Huge algae blooms quickly used up nutrients and were followed by great algae die-offs, changing the ecology of the lake. As the algae died, the decay process used up all the oxygen in some parts of the lake. When all the oxygen was gone, fish and other animals could no longer live in these parts of the lake.

Scientists call the aging process of a lake **eutrophication**. Natural eutrophication results as nutrients enter the lake and cause increased plant growth. Water drainage running off from the surrounding land into the lake, sediments from the bottom of the lake, and the living and dead plants and animals within the lake are natural sources of nutrients. Natural eutrophication is a slow process. People aged Lake Erie in a different way by over-fertilizing it with added nutrients. When human activity speeds eutrophication by overloading the lake with nutrients, the process is called **cultural eutrophication**.

Objectives:

When students have completed these activities, they should be able to:

1. describe the characteristics of oligotrophic and eutrophic lakes,
2. explain the effects of nutrient loading on lake habitats,
3. define nutrients as a limiting factor in lake habitats,
4. list sources of nutrient inputs to Lake Erie, and
5. explain how wetlands can improve water quality.

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Activity A: What happens when nutrients enter a lake?

Lakes that are low in nutrients are called **oligotrophic**. These lakes have low plant production and very clear water. They are often very deep and have a small surface area. Because they are so deep, wind and waves do not mix the water enough to stir nutrients throughout the lake. Sunlight does not reach the deep parts, either. Lake Superior is an example of an oligotrophic lake.

Lakes rich in nutrients are called **eutrophic**. Eutrophic lakes produce abundant plant life and have murky water. They are often shallow and have a large surface area. Because they are shallow, the water in these lakes is easily mixed by wind and waves, making nutrients available throughout the lake. Lake Erie is an example of a eutrophic lake.

What changes occur in the plant and animal life of a lake when nutrients enter the water? What happens if there are not enough of some nutrients in the lake?

Materials:

Three 1 quart glass jars, masking tape for labels, 1 to 2 gallons of recently gathered pond or lake water, stereo and/or standard microscopes, pond life identification guides, two goldfish, fish food flakes, and an incandescent light.

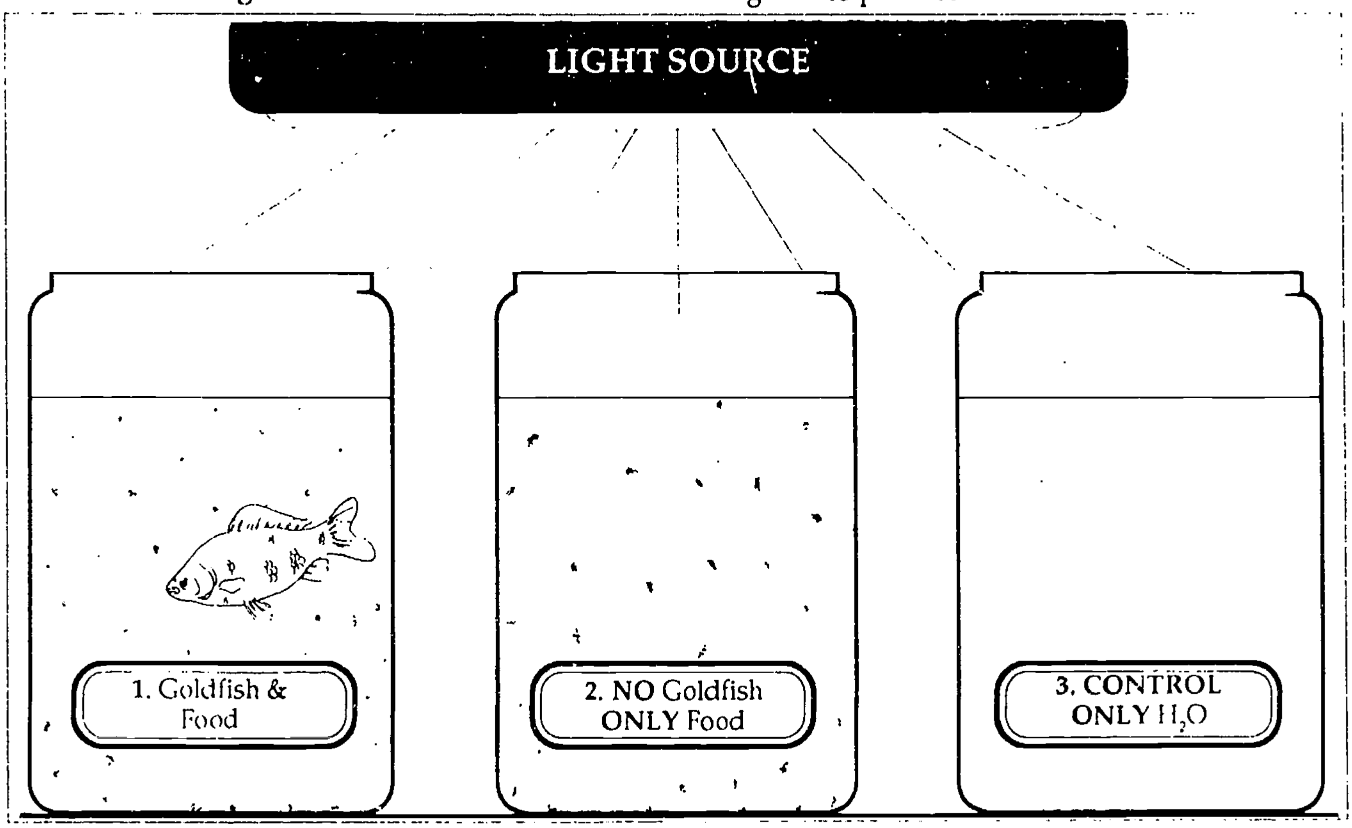
Procedure:

A. Label the three 1 quart jars as follows:
   1. Goldfish—feed daily
   2. Invisible Goldfish—feed daily
   3. Control—do not feed

B. Prepare each of the jars as follows:
   1. Goldfish—Fill the jar with lake water and add the two goldfish. Feed these goldfish every day with a pinch of fish food flakes.
   2. Invisible Goldfish—Fill the jar with lake water. Sprinkle each day with a pinch of fish food flakes. This jar should **not** contain goldfish.
   3. Control—Fill the jar with lake water. Do **not** put any goldfish or fish food in this jar.

C. If possible, add an aquarium bubbler to these three jars to add oxygen to the water. Set the jars aside in a visible and safe place. Place an incandescent light such as a gooseneck lamp above each jar. Leave the light on 24 hours a day.

D. Using the microscopes, look at some of the remaining lake water. Record your observations. You may want to draw some of the plants and animals you see and look them up in a guide to pond or lake life.



E. Each day during the observation period, check the jars for any changes. Record your observations. Some changes will be visible to the eye. You may also want to look at some of the water life with a microscope. Be sure to feed your goldfish every day.

In your lake water you are likely to see green and blue-green algae. Both kinds of algae need the nutrients phosphorus and nitrogen in order to grow. If there is not enough of these nutrients for algae to grow, these nutrients are said to be *limiting*: the lack of these nutrients limits or prevents algae from growing.

1. In jar #1, what is the source of nutrients entering the water? Where are nutrients coming from in jar #2? Are there any nutrients entering jar #3?

2. Which jar do you think will show the most algal growth? Which will show the least algal growth?

If both phosphorus and nitrogen are available in the water, the green algae will out compete the blue-green algae, mean more green algae will grow than blue-green algae.

3. In which jar has more green algae grown than blue-green algae?

Both green and blue-green algae will grow until all the nitrogen in the water is used up. The green algae will then stop growing. The nitrogen will have become the limiting nutrient for the green algae. The blue-green algae can keep growing after the nitrogen in the water is used up, because the blue-green algae can use nitrogen from the air. Thus, when nitrogen is limiting, the blue-green algae will out-compete the green algae, meaning more blue-green algae will grow than green algae.

4. In which jar is blue-green algae growing better?

5. What nutrient is limiting in jar #2? What nutrient do you think might become limiting in jar #1 (hint: the fish produces nitrogen in its wastes)? What nutrient appears to be limiting in the control jar (#3)?

The pictures below show species of algae living in Lake Erie. Some may appear in your jars.

Pollution tolerant green algae:

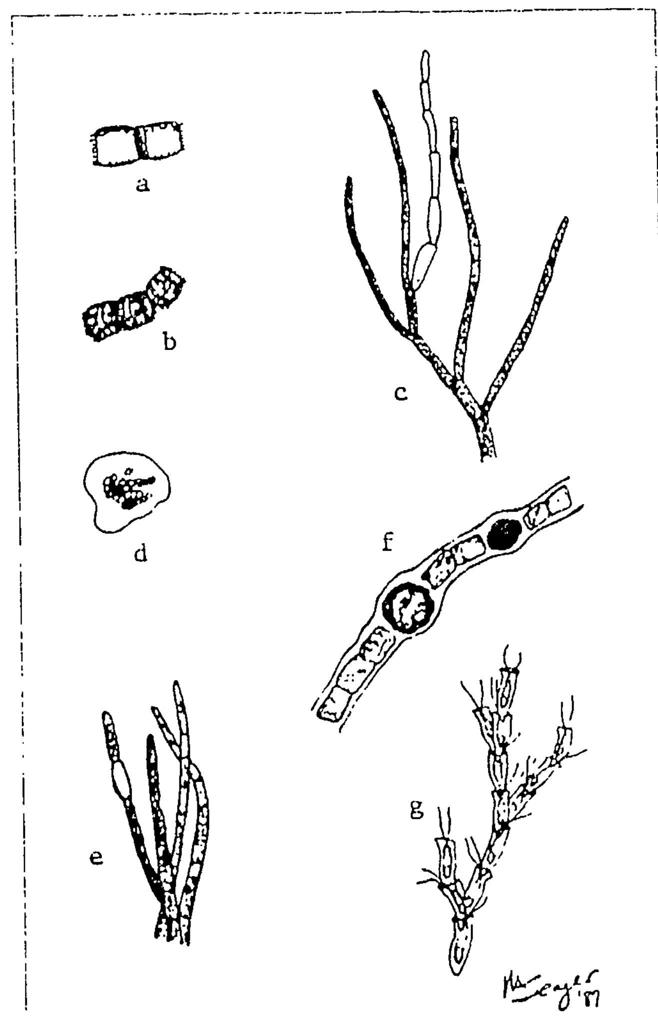
a) *Melosira*
b) *Stephanodiscus*
c) *Cladophora*

Pollution tolerant blue-green algae:

d) *Microcystis*
e) *Aphanizomenon*
f) *Anabaena*

Pollution intolerant form:

g) *Dinobryon*



Nitrate and Phosphate Data Chart

		DAY AFTER STORM (May 1985)										
Station	Nutrient	1	2	3	4	<u>5</u>	6	<u>7</u>	8	<u>9</u>	<u>10</u>	11
1	P (ppb)	283	82	70	94	60	32	40	49	40	35	30
	N (ppm)	6.5	6.9	9.7	12.4	10.5	9.5	7.8	6.5	6.6	6.5	6.6
2	P	104	97	79	79	50	35	21	12	10	7	3
	N	1.5	3.3	6.1	8.7	9.0	10.1	9.0	8.0	7.7	6.5	5.9
3	P	9	41	67	66	32	19	15	10	9	8	7
	N	.4	1.9	2.8	7.6	8.4	9.9	8.0	6.8	5.8	4.1	2.3
4	P	9	7	35	28	19	11	11	10	7	5	3
	N	.2	.3	2.4	3.3	5.1	8.8	8.7	8.4	6.5	4.8	2.2
5	P	8	11	10	22	20	16	12	10	6	3	2
	N	.2	.8	.6	2.6	4.9	9.7	7.8	6.9	6.0	4.1	2.3
6	P	9	5	10	26	19	11	10	10	8	6	5
	N	.5	.5	2.0	3.4	3.4	3.4	3.3	3.3	3.0	2.7	1.7
7	P	5	2	1	6	5	3	3	3	2	2	2
	N	.9	1.0	1.1	1.4	1.6	1.7	2.0	2.1	1.7	1.5	1.2

(Data for underlined dates were interpolated from those before and after the date. P and N were not measured directly on these days.)

Activity B: How do nutrients enter the Great Lakes?

How do phosphorus and nitrogen get into the Great Lakes? One way is from water runoff. Rainwater falling on farm fields, parking lots, roads, and backyards flows into creeks, streams, and rivers. The rainwater carries soil, fertilizers, and other pollutants it has washed from the land. You have probably seen how much more water creeks carry just after a storm and how muddy the water looks. Eventually, all this water runs into the lakes, bringing nutrients and other chemicals with it.

Materials:

Nitrate and Phosphate Data Chart, map of Old Woman Creek, graph paper, pencils, glass jar with lid, and soil.

Procedure:

A. Look at the map of Old Woman Creek. With your pencil trace the path of the creek starting at the point marked A.

1. Where does the creek go? Does water from the creek flow into Lake Erie?

B. On the same map, look at the land that is surrounded by the dotted line. All the land within this line is the watershed of Old Woman Creek. A **watershed** is all of the land drained by a creek, stream, or river. Water from this land runs off into Old Woman Creek, then through Old Woman Creek Estuary before reaching Lake Erie.

2. Are there any roads or farms in the Old Woman Creek watershed? How might these affect the water entering the creek?

C. The map also shows places in the estuary where scientists have tested the creek's water to see how much phosphorus and nitrogen it contains.

3. How many test stations are located in the estuary? Which station is closest to the lake? Which is closest to where the creek enters the estuary?

D. On a piece of graph paper, graph the concentration of phosphorus at Station 1 in the estuary for each day after the storm from day 1 to day 11. Use the data from the Nitrate and Phosphate Data Chart.

4. At Station 1, how many days after the storm were phosphorus levels the highest? When were phosphorus levels the lowest? How can you explain this?

E. Now graph phosphorus concentrations at Stations 3 and 6 for each day after the storm. If you use the same sheet of graph paper to draw this graph, be sure to label your lines Station 1, Station 3, and Station 6.

5. What day did peak (highest) phosphorus concentrations occur at Station 3? What day did phosphorus peak at Station 6? Can you explain why peak concentrations of phosphorus occurred later at Station 3 than at Station 1 and later at Station 6 than at Station 3?

F. Look at the data showing nitrogen concentrations at Stations 1, 3, and 7.

6. On what day do the peak concentrations of nitrogen occur at each station? Does it seem that the peak nitrogen concentrations are following the same kind of pattern that peak phosphorus concentrations showed?

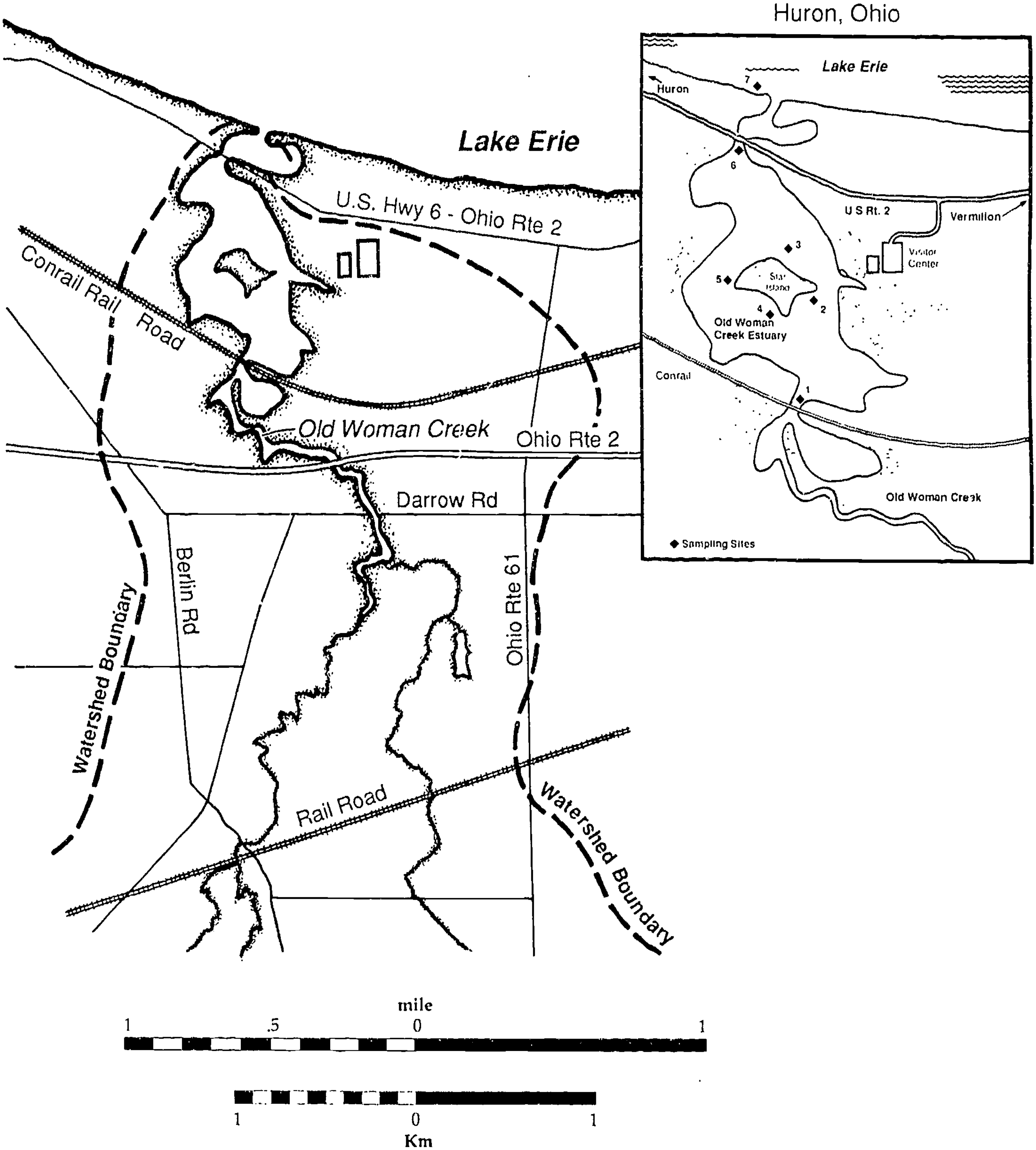
7. By day 9, has the peak in phosphorus and nitrogen concentrations occurred at all seven stations?

G. On a new sheet of graph paper, make a graph of the concentration of phosphorus at each station in the estuary on day 11.

8. For day 11, at which stations are phosphorus concentrations the highest? At which station are they the lowest?

H. On the same graph paper you used in step G, graph the concentration of nitrogen at each station in the estuary on day 11. (Note that N and P are not measured in the same units. This is consistent with the data collected, and it will help you to see the size of the changes in concentration.

Old Woman Creek Study Site
Huron, Ohio



The Old Woman Creek watershed with water test stations.

9. At which station are nitrogen concentrations the highest? At which station are they the lowest?

I. Fill a jar half full of water. Put a handful of soil into the jar. Shake the jar so that the water and soil are moving quickly and get mixed together. You have created muddy, stirred-up creek water in your jar. Wait a few minutes for the water to slow down and the soil to settle to the bottom of the jar. The water in the jar now is more like water in the estuary.

10. Where do you think estuary water will be the muddiest? Where will it be the clearest? What is one reason why phosphorus and nitrogen concentrations are lower at Station 7 than at Station 1?

11. The estuary has many plants growing in it. How might the plants affect the amount of nutrients reaching each station?

Estuaries and other wetlands act as "sinks" and "sponges" for nutrients. Nutrients settle out of the creek water and sink to the bottom of the estuary as the water passes slowly through the estuary. At the same time, nutrients are taken up by estuary plants.

12. How might an estuary's action as a "sink" and" sponge" for nutrients affect the lake into which the creek empties?

Review Questions:

1. What are the characteristics of oligotrophic and eutrophic lakes?

2. What happens when nutrients are readily available in, or are added to, a lake?

3. What is a limiting nutrient? What nutrients are usually limiting for algal growth in a lake?

4. What are some of the human-produced sources of nutrients entering the lakes?

5. How do estuaries act as "sinks" and "sponges," improving the quality of the water going through them to the lake?

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OHIO SEA GRANT COLLEGE PROGRAM

Nutrients in the Great Lakes (EP-029S)

Worksheet

NAME ______________________________

Activity A: What happens when nutrients enter a lake?

1. In jar #1, what is the source of nutrients entering the water? ______________________

   Where are nutrients coming from in jar #2? ______________________

   Are there any nutrients entering jar #3? ______________________

2. Which jar do you think will show the most algal growth? ______________________

   Which will show the least algal growth? ______________________

Use an extra page to record changes you see in each of the jars during the observation period.

3. In which jar has more green algae grown than blue-green algae? ______________________

4. In which jar is blue-green algae growing better than green algae? ______________________

5. What nutrient is limiting in jar #2? ______________________

   What nutrient do you think might become limiting in jar #1? ______________________

   What nutrient appears to be limiting in the control jar (#3)? ______________________

Activity B: How do nutrients enter a lake?

1. Where does the creek go? ______________________

   Does water from the creek flow into Lake Erie? ______________________

2. Are there any roads or farms in the Old Woman Creek watershed? ______________________

   How might these affect the water entering the creek? ______________________

   ____

3. How many test stations are located in the estuary? ______________________

   Which station is closest to the lake? ______________________

   Which is closest to where the creek enters the estuary? ______________________

4. At Station 1, how many days after the storm were phosphorus levels the highest? ______________________

   When were phosphorus levels the lowest? ______________________

ERIC

How can you explain this? ______________________________

____

5. What day did peak (highest) phosphorus concentrations occur at Station 3? ______________

What day did phosphorus peak at Station 6? ______________________________

Can you explain why peak concentrations of phosphorus occurred later at Station 3 than at Station 1, and later at Station 6 than at Station 3? ______________________________

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8. For day 9, at which station are phosphorus concentrations the highest? ______________

At which station are they the lowest? ______________________________

9. At which station are nitrogen concentrations the highest? ______________________________

At which station are they the lowest? ______________________________

10. How can you explain the decrease in phosphorus and nitrogen concentrations from Station 1 to Station 7? ______________________________

11. Where do you think estuary water will be the muddiest? Where will it be the clearest? ________

____

What is another reason why phosphorus and nitrogen concentrations are lower at Station 7 than at Station 1? ______________________________

12. How might an estuary's action as a "sink" and "sponge" for nutrients affect the lake into which the creek empties? ______________________________

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