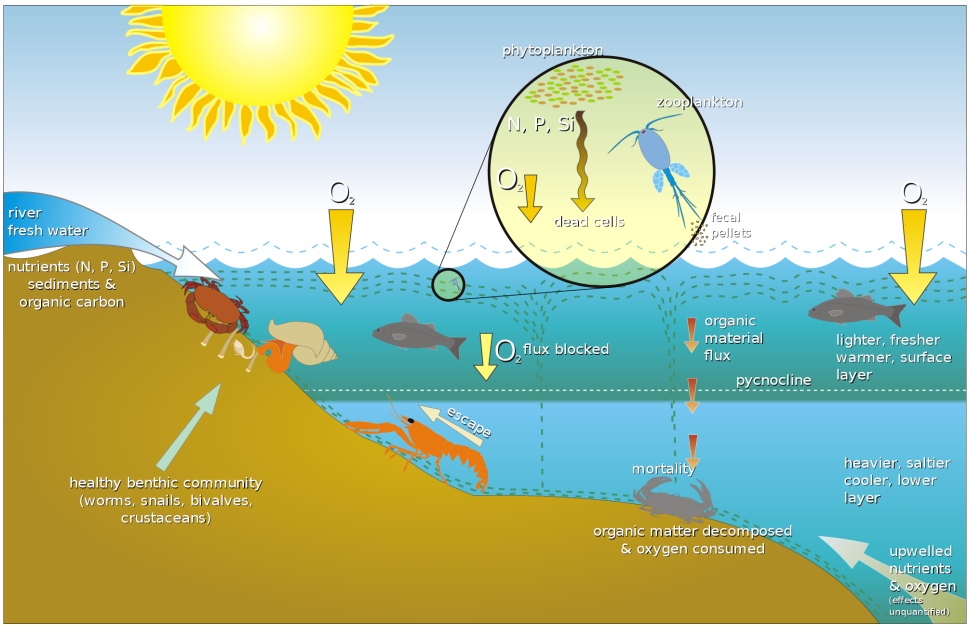

https://en.wikipedia.org/wiki/Fish_kill 1

Ecosystems: Interactions, Energy, and Dynamics

Grades 6-8

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Anchoring phenomenon: Fish kills in the Hood Canal
Essential question about phenomenon/unit: What causes fish kills in the Hood Canal?

Scientific explanation: Hypoxia due to low levels of dissolved oxygen in the water.

NGSS *Performance Expectations* addressed in this unit:

Standard	PE	DCI	CCC
MS-LS1-6	Constructing Explanations and Designing Solutions	Organization for Matter and Energy Flow in Organisms; Energy in Chemical Processes and Everyday Life	Energy and Matter
MS-LS2-1	Analyzing and Interpreting Data	Interdependent Relationships in Ecosystems	Cause and Effect
MS-LS2-3	Developing and Using Models	Cycle of Matter and Energy Transfer in Ecosystems	Energy and Matter
MS-LS2-4	Engaging in Argument from Evidence	Ecosystem Dynamics, Functioning, and Resilience	Stability and Change

Summary Table of Activities in Unit

Activity	***Learning Target***	***Evidence Students Could Gain***	***Connection to Phenomena***
Activity 1: Initial Model	Students will express their understanding of phenomena of fish kills in Hood Canal, Washington by creating a model.	Students will be able to use their background knowledge from previous learning experiences to create their initial model. Additionally, students will work in groups, and thus have the opportunity to bounce ideas off of each other.	Students will express their initial understanding of the phenomena
Activity 2: Photosynthesis/Respiration and BTB	Students will understand how respiration and photosynthesis can change the pH level of water.	Students will see how BTB, which is a pH indicator (green = acidic, blue = basic), can be used to observe photosynthesis and respiration in the water.	Students will explain that marine animals decrease oxygen, marine plants add oxygen, and oxygen can be added to the ocean from the atmosphere
Activity 3: Fish Tank	Students will observe how marine organisms decrease oxygen levels in the water as the organisms respirate.	Students will measure the change in oxygen levels as fish respirate in the tank.	Students will explain why marine organisms need certain levels of dissolved oxygen in the water to survive.
Activity 4: Water Circulation	Students will understand that certain places in the ocean are stratified, meaning that there are water layers that don't mix together.	Students will demonstrate how stratified water could be mixed by wind and waves without touching bowl of water by blowing across the water.	Students will explain that 1) deep, stratified water will run low on oxygen because it is used up in respiration, but not replenished from the

			atmosphere or photosynthesizers and 2) winds and waves can mix water.
Activity 5: NANOOS Data Exploration	Students will understand the biophysical conditions that could cause fish kills.	Students will explore real ocean data that was collected in Puget Sound and posted online.	Students will explore and interpret real data about oxygen levels in Hood Canal by using a website user-interface with buoy dat.
Activity 6: Intro to R	Students will observe how oxygen levels change over time and water depth.	Students will explore data from NANOOS using a programming language, R.	Students will explore and interpret real data about oxygen levels in Hood Canal by using R programing to generate plots.
Activity 7: Evidence Tracker	Students will develop an evidence tracker to generate claims, evidence, and reasoning that they have developed over the course of the lesson.	Student will fill out their evidence tracker from their work from days 1-4 is passed back.	Students will connect claims, evidence, and reasoning to explain what causes fish kills in Hood Canal.

Summary of Student Survey Results

Sixty-five students from three classes filled out a learning evaluation and feedback form after completing the full module. Of the four different lesson modules with hands-on activities (Lesson 2 - Rotation Activity (Goldfish, Water Circulation, BTB); Lesson 3 - Exploring NANOOS; Lesson 4 - Coding and making graphs with R; Lesson 5 - Writing the CER) students report learning the most during Lesson 2, with over 70% of students saying they learned a lot. Approximately 50% of students report learning a lot during the NANOOS website exploration and coding, while approximately 43% report learning a lot while writing the CER. Open ended feedback from the students highlights that having individual computers to work on for Lessons 3 and 4 would have been helpful rather than working in teams. Additionally, this module was taught at the end of the school year, and students express that it would have been better earlier in the year when they felt more focused. Finally, while lesson 4 is currently designed to use the programming language R, students indicate that they would be interested in learning other languages such as Java or Python. After completing the full module, 64% of students reported feeling more comfortable with coding, and several students indicated that they enjoyed learning about Hood Canal.

Lesson 1

Objective: To learn about the week, define phenomena, and express your understanding of fish kills in the Hood Canal.

NGSS:

1. MS-LS2-3 Ecosystems: Interactions, Energy, and Dynamics
   Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.
2. MS-LS2-4 Ecosystems: Interactions, Energy, and Dynamics
   Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

Agenda

Introductions- 5 minutes
Week- 5 minutes
Phenomena- 15 minutes
Model of Fish Kills- 20 minutes
Evidence Tracker!- 10 minutes

Summary of Tasks

Define Model and Phenomenon

1. Start with the students defining model and phenomenon.
2. Do a think/pair/share.
3. Show the students examples

Introduction

1. Names
2. Expectations
   SDRA- Think/Pair/Share-What is an expectation?
   SDRA- Think/Pair/Share- What are expectations set in classrooms?
   SDRA- Think/Pair/Share- What is an important expectation to you?
3. Talk about each day and the goal for each day.

Model of Fish Kills- We have a specific phenomena that will investigate this week-- Fish Kills in the Hood Canal. Show the students where the Hood Canal is located. What this video: http://www.seattletimes.com/seattle-news/environment/lack-of-oxygen-killing-marine-life-in-hood-canal-waters/

1. Show the students a video/image/description of a fish kill
   a. Pass out a passage for all of the students to read: Last Fall you and your friend were camping near Hood Canal in the Puget Sound for a weekend. One the first

day you both walk down the water and notice a vibrant ecosystem. You see lots of birds, some crabs, and you even see some fish swimming in the water. You walk down to the water and notice this (show the image of the video of the fish). A few hours later you walk down the water and there are lots of dead fish floating in the water. You even notice that crabs and ___ have existed the water or are near the show...see handout below

2. For five minutes, instruct the students to write down/draw what they already know about fish kills and to write down what questions they still have. [Prob with what kills a fish, what do you know about the puget sound, what do fish need, what abiotic and biotic factors exist in this system]. Have them write down their thoughts in the "What do I know?" column:

What do I know?	What questions do I still have?	What did I learn from others?

3. Break the students into six groups of five. Identify a timer, a drawer, a question developer, and a leader for each group.
4. Instruct them each student to share what they know and what questions that still have. While students share, the others should write down things they learn and new questions that arise.
5. Then the students will create a model on the back of their evidence tracker. You may need to explain what a model is to the students. Each drawing must be ask detailed as possible. This should include drawings and words.
6. Share with another group.
7. Edit their model.

Evidence Tracker!- Instruct the students to draw out an "Evidence Tracker."

Process	Claim	Connection to Phenomena
1. Nutrients 2. Source of O2 3. Fate of O2 4. Source of CO2 5. Fate of CO2 6. Water Circulation		

Materials: posters, markers, powerpoint, these videos:

- https://www.youtube.com/watch?v=dzjkoC6up-s#action=share
- https://www.nasa.gov/feature/goddard/2016/eye-popping-view-of-co2-critical-step-for-carbon-cycle-science
- Fill Kills story
- Phenomenon/Model and Expectation worksheet

References

Accommodations

The Phenomenon- Fish Kills

Last **September** you and your family went for a day trip to a park located 0.23 miles from the **Hood Canal** in the **Puget Sound**. **That day you witnessed a marine phenomenon that you'll never forget!**

During your day at the park, you decided to walk down to the shore of the Hood Canal. Once you arrived at the shore you noticed an informational sign. As a studious person, you decided to read the sign, which stated the following, "the Hood Canal is **long and narrow basin** of the Puget Sound with an average width of 1.5 miles and a **mean depth of 177 feet**. The canal has 212.9 miles of shoreline!" Also, you learned that, "the source of **saltwater** in the Hood Canal is the **Pacific Ocean** and several **rivers** that flow into Hood Canal, mostly from the Olympic Peninsula and the Kitsap Peninsula, are the source of **freshwater**." This made you wonder how often **water enters and leaves the canal**. But, suddenly, a **hermit crab** on your toe distracted you!

As you walked along the shore, you noticed a vibrant ecosystem! In total you observed **three bald eagles**, **one woodpecker**, **three more hermit crabs**, and **12 purple shore crabs**. Honestly, you were surprised to see so many hermit crabs and purple shore crabs. As a Seattleite, you've seen shore crabs at Golden Gardens, but usually you find two or three after searching for a long time. This made you **wonder why** for a couple of minutes and then suddenly you saw a **fish** swimming in the water! Then you saw **more fish**! Most of them were **near the surface of the water**. You recall that the **behavior of the fish** seemed odd—they were moving really slowly. Also, **the number of fish** was really surprising to you. As you walked down to the water you noticed this….

[*Please watch the video on the screen*]

However, you also notice it's 11:30 am and decided to return to your family for lunch. About **2 hours later** you walked down to the shore because, again, it's not everyday you see a total of **four hermit crabs**, **12 purple shore crabs**, **three bald eagles**, **a woodpecker**, and **tons of fish**!

Once you arrived at the shore you noticed that all of the **fish were dead.** However, you notice even more **hermit crabs** and **purple shore crabs on the rocky shore away from the water** than before you ate lunch. **What killed the fish?**

What do I know?	What questions do I still have?	What did I learn from others?

Name_____ Class Period_____ Date_____

Directions: Please write and draw out a definition for “phenomenon” and “model” in the following boxes.

Phenomenon	Model

Expectations

The Phenomenon- Fish Kills

Last **September** you and your family went for a day trip to a park located 0.23 miles from the **Hood Canal** in the **Puget Sound**. **That day you witnessed a marine phenomenon that you'll never forget!**

During your **first day** at the rustic cabin, you decided to walk down to the shore of the Hood Canal. Once you arrived at the shore you noticed an informational sign. As a studious person, you decided to read the sign, which stated the following, "The Hood Canal is **long and narrow basin** of the Puget Sound with an average width of 1.5 miles and a **mean depth of 177 feet**. The canal has 212.9 miles of shoreline!" Also, you learned that, "The source of **saltwater** in the Hood Canal is the **Pacific Ocean** and several **rivers** that flow into Hood Canal, mostly from the Olympic Peninsula and the Kitsap Peninsula, are the source of **freshwater**." This made you wonder how often **water enters and leaves the canal**. But, suddenly, a **hermit crab** on your toe distracted you!

As you walked along the shore, you noticed a vibrant ecosystem! In total you observed **three bald eagles**, **one woodpecker**, **three more hermit crabs**, and **12 purple shore crabs**. Honestly, you were surprised to see so many hermit crabs and purple shore crabs. As a Seattleite, you've seen shore crabs at Golden Gardens, but usually you find two or three after searching for a long time. This made you **wonder why** for a couple of minutes and then suddenly you saw a **fish** swimming in the water! Then you saw **more fish**! Most of them were **near the surface of the water**. You recall that the **behavior of the fish** seemed odd—they were moving really slowly. Also, **the number of fish** was really surprising to you. As you walked down to the water you noticed this….

[*Please watch the video on the screen*]

However, you also notice its 11:30 am and decided to return to the rustic cabin for lunch. About **2 hours later** you walked down to the shore because, again, it's not everyday you see a total of **four hermit crabs**, **12 purple shore crabs**, **three bald eagles**, **a woodpecker**, and **tons of fish**!

Once you arrived at the shore you noticed that all of the **fish were dead.** However, you notice even more **hermit crabs** and **purple shore crabs on the rocky shore away from the water** than before you ate lunch. **What killed the fish?**

What do I know?	What questions do I still have?	What did I learn from others?

Name_____ Class Period_____ Date_____

Directions: Please write and draw out a definition for "phenomenon" and "model" in the following boxes.

Phenomenon

Model

Expectations

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

Lesson 2

Objective: Use inquiry-based activities to analyze and evaluate relationships between photosynthesis, respiration, circulation, oxygen levels, and fish kills in Hood Canal.

NGSS:

1. MS-LS1-6 From Molecules to Organisms: Structures and Processes
   Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms.
2. MS-LS2-3 Ecosystems: Interactions, Energy, and Dynamics
   Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.

Agenda

Introduction - 10 minutes
Activities - 10 minutes each, 30 minutes total
Conclusion - 10 minutes

Summary of Tasks

<u>Engage</u>

Introduction

1. Explain objective
2. Split into three groups for activities
3. Have groups discuss what they know about photosynthesis, respiration, water circulation, and oxygen levels. Afterwards, students will share answers with class and instructor will write conclusions on the board.
    a. Photosynthesis and Respiration:
        i. Photosynthesis: What are ingredients? What are outputs?
        ii. Respiration: What are ingredients? What are outputs?
    b. Ocean Circulation and Oxygen:
        i. What causes ocean water to move?
        ii. How does water movement affect where oxygen, CO_2, and nutrients are in the ocean?
    c. How are fish affected by photosynthesis, respiration, and circulation in the ocean?

<u>Explore, Explain, and Elaborate</u>

Activity: Photosynthesis/Respiration and BTB

1. Ask students if they have used BTB (bromothymol blue) before
    a. Yes? Explain their experience to class.
    b. No? Instructor explains BTB to class.

        i. BTB is a pH indicator (green = acidic, blue = basic) and can be used to observe photosynthesis and respiration. When carbon dioxide is added to the solution, carbonic acid is formed, and the solution turns from green to yellow.
2. Provide students with a container of BTB, a straw, and a pipette.
3. Students brainstorm how they think they can make BTB turn yellow then test their hypothesis
    a. One approach will be for students to blow into the straw
4. Ask students if they can turn the solution back to green, or even to blue?
    a. One approach will be for students to pipette air into the solution
5. Students explain what this color change indicates and how this activity is related to oxygen in the ocean.
    a. Students should explain that marine animals decrease oxygen, marine plants add oxygen, and oxygen can be added to the ocean from the atmosphere

Activity: Fish Tank

a. Show students the container with fish. Explain that the fish were just put in the water at the beginning of class.
b. Ask students if they think the oxygen will be higher or lower now than 10 minutes ago. Students share hypothesis and reasoning.
    i. Oxygen levels should be lower. Oxygen is being used in fish respiration but not being replenished because the water surface is calm (little air is being entrained)
c. Read oxygen level.
d. Ask students to plot new data point and explain the oxygen level readings.
e. Think/Pair/Share these questions:
    i. Why is it continuing to slowly decrease?
        1. Fish are breathing oxygen. This is called respiration.
    ii. What would happen if the fish were left in this water for a long time?
        1. Oxygen levels would continue to decrease and fish would die.
    iii. So why don't all fish die in fish tanks at home?
        1. Tanks normally have a filter or bubbler that adds oxygen. Many people also put plants in their fish tank to photosynthesise and add oxygen.
    iv. So why don't all fish die in the ocean?
        1. Wind and waves mix oxygen from the air into the water. Marine plant photosynthesis and add oxygen to water.
f. If there is still time, read oxygen levels again and add to chart.

Activity: Water Circulation

1. Think, Pair Share. Ask students to define density and give an example of seeing density work in real life
    a. Density = Mass / Volume. In other words, how compact something is.
    b. Examples: helium balloon floats, milk sinks to bottom of tea, hot air balloons fly
2. Ask students if they think freshwater or saltwater is denser

    a. Lead them towards the answer by thinking about how easy it is to float in the ocean, but not in a pool or bathtub
3. Show students experiment and ask what they think will happen
    a. Start with bowl of freshwater (dyed red)
    b. Slowly pour in saltwater (dyed blue)
    c. Saltwater should sink to bottom and settle
4. Tell students that some places in the ocean are like this. They are stratified, meaning that there are water layers that don't mix together.
5. Ask students how they think that water is mixed in the ocean.
    a. Answer: wind, waves, currents, tides, etc.
6. Students try to demonstrate how stratified water could be mixed by wind and waves without touching bowl of water
    a. Possible approach: students blow across the water surface and water becomes mixed to purple
7. Students explain what this color change indicates and answer questions.
    a. How is this activity related to oxygen in the ocean? If fish live throughout the water column and sunlight only reaches through the upper layer, where is oxygen produced? Where is it consumed?
        i. Students should explain that:
            1. Deep, stratified water will run low on oxygen because it is used up in respiration, but not replenished from atmosphere or photosynthesizers
            2. Winds and waves can mix water and can 1) bring surface oxygen to deeper areas that used to be low on oxygen so that fish have enough oxygen to live or 2) mix low-oxygen deep water throughout the water column so that even the surface water doesn't have enough oxygen for fish to live.
    b. What else might be moved around in the water by wind and waves? What else would affect fish?
        i. Possible answers: food, nutrients, pollutants

Evaluate

Conclusion

Fill out Evidence Tracker in groups or as a class, depending on time available.

Process	Claim	Connection to Phenomena
1. Nutrients 2. Source of O2 3. Fate of O2 4. Source of CO2 5. Fate of CO2 6. Water Circulation		

Materials

Activity: Photosynthesis/Respiration and BTB

~50 ml BTB
1 clear cup / student
1 straw / student
1 plastic pipette / student

Activity: Fish Tank

1 five-pint mason jar, or other similar container with a small opening
1-3 HEALTHY goldfish
1 oxygen sensor with instant digital readout

Activity: Water Circulation

1 large, deep and wide, clear container
Water (amount will depend on container size)
Red dye
Blue dye

Teacher Preparation

Activity: Photosynthesis/Respiration and BTB

1. Make BTB indicator solution for student groups
2. Make a dilute universal indicator solution for this demonstration and for each student group by combining 750 mL water with 30 mL universal indicator solution.
3. Pour about 25 mL of this dilute universal indicator solution into a clean cup for each student.

Activity: Fish Tank

1. At least 24 hours before activity, fill container with water and let equilibrate with room temperature and atmospheric oxygen
2. Immediately before class starts, measure oxygen in open container (it may take up to 5 minutes for oxygen sensor to come to correct reading). After recording oxygen levels, add fish to the container.

3. Add first data point (time, oxygen level) to chart.
4. Note: Fish thrive in oxygen levels >5 ppm (223 um/m3) and may die if levels fall below 2 ppm (89 um/m3). Constantly monitor oxygen levels. If levels fall below ~150 um/m3, remove fish from container and place in fresh oxygenated water.

Activity: Water Circulation

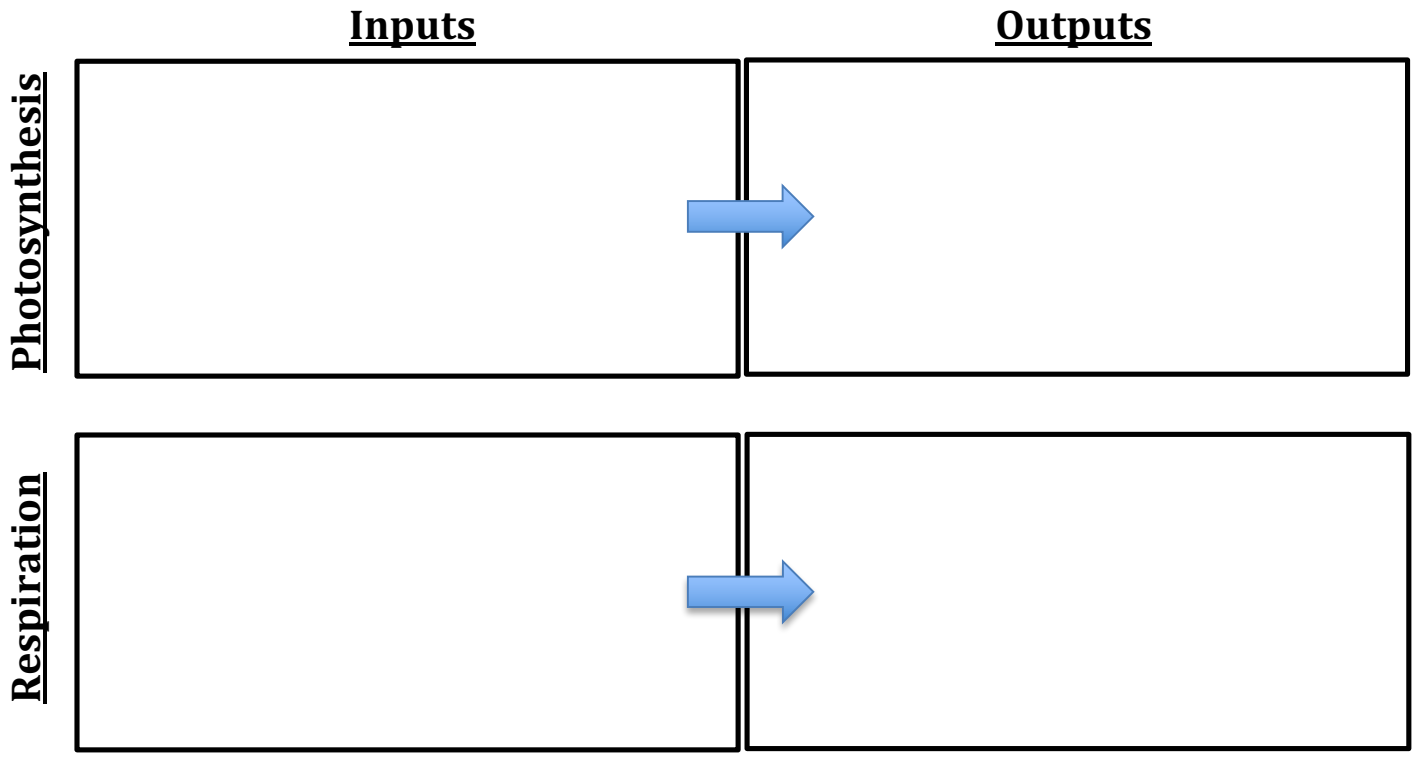
1. Make saltwater
    a. Boil water, add as much salt as will dissolve, let water cool
2. Dye freshwater and saltwater
3. Fill bowl ¾ full of freshwater
4. Fill large cup with saltwater
5. Either make three sets of this activity or be prepared to restage with every new group

Fish Kills Evidence Tracker

Process	Claim	Connection to Phenomena
Nutrients		
Source of Oxygen		
Fate of Oxygen		
Source of Carbon Dioxide		
Fate of Carbon Dioxide		
Water Circulation		

Name_____ Class Period_____ Date_____

Directions: Please write and/or draw out the inputs and outputs of photosynthesis and respiration.



What causes ocean water to move? Write a list.

_____

_____

_____

_____

How are fish affected by photosynthesis, respiration, and circulation in the ocean?

_____

_____

_____

_____

Lesson 3

Objective: To explore and interpret real data about oxygen levels in Hood Canal by using a website user-interface with buoy data

NGSS:

1. MS-LS1-6 From Molecules to Organisms: Structures and Processes
   Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms.
2. MS-LS2-1 Ecosystems: Interactions, Energy, and Dynamics
   Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.
3. MS-LS2-3 Ecosystems: Interactions, Energy, and Dynamics
   Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.
4. MS-LS2-4 Ecosystems: Interactions, Energy, and Dynamics
   Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

Agenda

Introduction- 10 minutes
NANOOS - 35 minutes
Evidence Tracker!- 5 minutes

Summary of Tasks

<u>Engage</u>

Introduction

1. Explain objective
   a. Today we are going to explore real data that was collected in Puget Sound and posted online. This data will be our evidence that we can use to develope claims connected to our phenomena (fish kills).
2. Recap what we have learned this week:
   a. Animals consume O2 and produce CO2. This is called respiration.
   b. Plants consume CO2 and produce O2. This is called photosynthesis. Because plants need sunlight to photosynthesize, they mainly produce oxygen near the water surface.
   c. Water can receive oxygen when it is in contact with the atmosphere. This increases the oxygen near the water surface.
   d. When water doesn't circulate, denser water remains deep and has low oxygen while less dense water remains shallow and has high oxygen.
   e. Wind and waves cause water to circulate and mixes the oxygen and other nutrients throughout the water column.
3. Split into small groups of 2-3.

a. Lead students through slides 1-3 in the PowerPoint presentation (resources folder) using think/pair/share to answer questions.

Explore, Explain, and Elaborate

Activity: NANOOS Data Exploration

1. Each student can work on a computer, but students should complete the questions in small groups
2. Follow the instructions in the student guide for Lesson 3.

Evaluate

Conclusion

1. Lead students through slides 4-5 in the PowerPoint presentation (resources folder) asking students to provide explanations for the maps.

Materials

Computers
Internet Access
Colored Pencils (red, green, blue)
Powerpoint for teachers (in Resources folder)

The Northwest Association of Networked Ocean Observing Systems (NANOOS) is a website that provides information and data about the ocean. We are going to use this website to explore oxygen in Hood Canal.

1. Go to http://www.nanoos.org/

2. Scroll down to Quick Links. Click on Data Exploration and Visualization.

3. Click on Data Explorer.
    a. You should see a map of the Pacific Coast with many symbols in the ocean.
    b. Click on the legend to find out what these symbols mean. We will focus on Buoy data. What symbol represents a buoy?_____

4. Zoom in to Puget Sound and Hood Canal. There are four buoys in Hood Canal, two near the North end and two near the south end. Make sure you see these buoys.

5. Click on the northernmost buoy called ORCA Hansville.
    a. On the right side of your screen, you should see a list of data types that you can explore. Click on Oxygen Concentration.
    b. There should be a plot below Oxygen Concentration.
        i. What is the x-axis?_____
        ii. What is the y-axis?_____ -_____
        iii. How much different is the oxygen level at the surface compared to the oxygen level at depth? Show your math and final answer.

        iv. Fish thrive when oxygen is >5 mg/L.
        The suffer when oxygen is <5 mg/L.
        They can die when oxygen falls below 2 mg/L.
        Based on this graph, are fish healthy at the surface? _____
        At depth? _____
    c. The panel at the bottom of your screen also shows the data of whichever data type you have clicked on for times when data is available. Right now, it shows oxygen in May 2017.
        i. What is the x-axis? _____
        ii. What is the y-axis? _____
        iii. What do the colors mean? _____
        iv. If you hover your mouse over this graph, you can see data for the specific location of your pointer. If you click around on this graph, the plot you looked at previously will change to show data for the selected time.
        v. What are two major observations from looking at the whole month of oxygen data? (Think about overall what you observe in the surface vs

deep water, day to day, etc.)
1._____
2._____

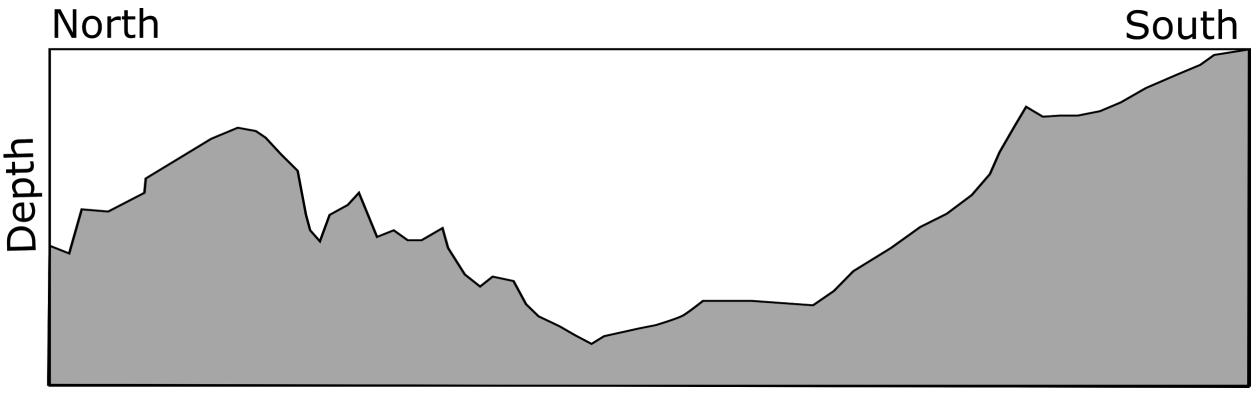
6. Now let's explore another location. Click on the southernmost buoy called ORCA Twanoh.
    a. Click on Oxygen Concentration on the right side of your screen and explore the data shown here. Think about how this location differs from the previous location.
    b. How much different is the oxygen level at the surface compared to the oxygen level at depth? Show your math and final answer.

    c. How does this number compare to the difference you found for the northern location?_____
    You can use this comparison to predict which location has more water circulation. Which location has more water circulation? How do you know?
    _____
    d. What are two major observations from looking at the whole month of oxygen data? (Think about overall what you observe in the surface vs deep water, day to day, etc.)
    1._____
    2. _____
    e. Look at data from April 1st. If you were a fisherman, at what depth range would you cast your line? Why?
    _____
    f. Think back to the water circulation activity you did yesterday. At the start of the activity, the water was stratified (the denser water sank to the bottom and didn't mix with the surface water). When you blew across the water surface, you created wind that pushed water across the surface and pulled water up from depth. Think about how that activity relates to this buoy location.
    If wind blew strongly from the northeast, where would surface water move to?
    _____
    Where would deep water move to?
    _____
    Would you go fishing after this windy day?
    _____

7. Use what you just learned to make your own maps of Hood Canal. Color in the white part of the map below to show how much oxygen is in the deep water in Hood Canal.
    a. Color red where oxygen is low, green where oxygen is moderate, and blue where oxygen is high.

b. Draw fish where they would like to live and X's where fish would die.

8. Color in the white part of the map below to show oxygen levels throughout the water column in Hood Canal.
    a. Color red where oxygen is low, green where oxygen is moderate, and blue where oxygen is high.
    b. Draw fish where they would like to live and X's where fish would die.



9. Now that you've gotten the hang of navigating this site and interpreting the graphs, explore on your own. Look at at least two different buoys and make at least five major and new observations. These observations can include trends through time, between different locations, or different data types.

Buoy Name	Observation

Lesson 4

Objective: To explore and interpret real data about oxygen levels in Hood Canal by using R programing to generate plots

NGSS:

1. MS-LS2-1 Ecosystems: Interactions, Energy, and Dynamics
   Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

Agenda

Introduction (10 min)
Part 1: Hands on making a plot in R (20 min)
Part 2: Hands on in groups making and interpreting plots in R (30 min)
Conclusion (10 min)

Note: Part 1 and Part 2 essentially produce the same figures. Part 1 breaks down the code step by step while Part 2 just uses the code. For beginners, it may be better to skip straight to Part 2 or to split this activity into two days.

Summary of Tasks

<u>Engage</u>

Introduction

1. Explain objective
   a. Today we are going to explore the same data as yesterday but using a computer programming language called R to make our own plots.
   b. During the first part of the class we will learn to use (or 'speak') R, then we will use it to explore the data, then we will report our findings on our evidence tracker.
   c. Why might it be helpful to use programming when exploring our data?

<u>Explore, Explain, and Elaborate</u>

Activity: Intro to R and hands on setup

1. Walk through basics of programming (see PowerPoint and student handout)
2. Have students read the tips on their handout and if any student have coded before have them share their own tips.

Activity: Making an Oxygen depth profile plot in R

1. Each student can work independently
2. Follow the instructions in the student guide for the Oxygen depth profile.

Activity: Making and interpreting plots in R

1. Each student can work on a computer, but students should complete the questions in small groups
1. Follow the instructions in the student guide for lesson 4.

2. Notes for teachers: Fish kills didn't happen in 2012 because oxygen never got low enough throughout the whole water column. In order to have fish kills you need low oxygen even at the surface. Fish kills did happen in 2015. There was low oxygen throughout most of the water column for much of the summer in 2015, but only when it reached the surface (due to wind driven currents) on August 29th, 2015 did a fish kill actually occur.

Evaluate

Conclusion

Discuss last slide of provided PowerPoint as a class.

Materials

Computers

Internet Access

R program downloaded on all computers - if possible, have R downloaded on all computers before class to save time in the activity and troubleshoot any problems with the software on classroom computers

Handout for students (in Resources folder)

Powerpoint for teachers (in Resources folder)

Files needed for R coding (in R-coding folder)

R Coding Basics:

- In the language R, we assign things names. So we can assign the number 8 to be named Pizza by typing `Pizza <- 8`. Whenever you see the <- symbol (sometimes called an arrow or a carrot), it means that we are assigning something to a name, so we can refer to it again later more easily.
- Once things are named, it is easier to do things to them. Back to our Pizza example, we could add: `Pizza + Pizza`, which should give us 16. Or divide `Pizza/2` which would give us 4.
- We can use R to do much more than basic arithmetic. We can take the average of many numbers, do the same math operation to a bunch of numbers all at once, make plots, and more. This is done using what we call functions. Each function has a name that we call then then is followed by parenthesis. We put the object that we want the function to act on in the parentheses. For example, if we want to take the average, or mean, of five numbers we can use the function `mean()` and put the numbers inside the parentheses like so:

  `mean(1:5)` where 1:5 is the numbers 1 through 5 (1,2,3,4,5)
  we could write the same thing by making a list using the function c()
  `mean(c(1,2,3,4,5))`
  or by naming that list to an object and then taking the mean of that object like so:

```
mylist <- c(1,2,3,4,5)
mean(mylist)
```

Tips for coding:

- In this procedure, lines of code that you want to type will be in the font Calibri instead of the font Times New Roman, hopefully this makes it clear what exactly you need to type.
- Type carefully. Your computer does what you actually type, not what you meant to type!
- Spaces, capitalization, and the direction of slashes (/ vs \) matter.
- If you want to re-run a line of code that you already typed, hit the up arrow to scroll through the last few lines you ran.
- If you start typing something and then hit tab, sometimes the computer will automatically fill in the rest of the word for you.
- We can interrupt a script or a line of code by typing ctrl-C and then hitting enter.

Set up:

- Open up R
- Check what directory you are in by typing:

  ```
  getwd()
  ```
- Change to be in the folder you downloaded onto the desktop by typing:
  example:

  ```
  setwd("G:/kugrevstad/Write/RLabProject")
  ```
- Make sure you're in the right place by typing `getwd()` again
  - Troubleshooting tip: You can double check your folder location if you open it up and double click on the file that ends in ".R". In the R console it should read out where the file was located. Use that directory location and try typing `setwd("That-directory-location")`.

Part 1: Making a single plot:

1. Load the required tools by typing:
   ```
   require(R.matlab)
   ```

2. Load the data, in this case, from 2012
   ```
   mydata <- readMat("TW_2012.mat")
   ```

3. Check to see what the data has in it by typing:
   ```
   names(mydata)
   ```
   a. This will tell you the different kinds of information stored in this dataset. The names are a bit hard to interpret, but make your best guess as to what they contain

   ```
   str(mydata)
   ```
   b. This will tell you a bit more information about the structure of the data. You can tell that there are 8 parts to this data, each part has a name, each part contains a lot of numbers in a matrix of dimensions 30x2640. This means that there are 30 rows and 2640 columns in each of these 8 dimensions! Wow! That is a lot of data!
   c. Each column is a day and time that a depth profile of data was collected, each row represents one depth along that depth profile.

4. If we want to plot data from a certain day or time, we need to know what the time variable looks like. Type:
   ```
   str(mydata$TWtime.2012)
   ```
   a. The first row is missing (NaN means there is no data there), but then the numbers start at 4384. How is this a date and time!? Well, this data has been counting the days since January 1, 2000.
   b. To get to day of year, something a little more easy to understand: find the

minimum value of all the days for this year (aka Jan, 1)
minimumday <- min(mydata$TWtime.2012, na.rm = T)

c. Round down (floor) to get the integer rather than the decimal version
floor(minimumday)
d. subtract this number from the rest of the values to get a Day of Year (DoY) where 1 = Jan 1, 2 = Jan 2, etc
DoY_2012 <- mydata$TWtime.2012 - floor(minimumday)
e. Now we can type
str(DoY_2012)
f. To see what the new day of year matrix looks like. You should still have the NaN as the first thing, but then numbers less than 1, like 0.011, meaning the data were taken on Jan 1, 2012.

5. We can take the average of each column (remember each column is one depth profile of data) to just get the day that each profile was taken
DoY_2012_ave <- colMeans(DoY_2012, na.rm=T)

6. Now we can use this new list to get the data from a particular day.
   a. First we specify what day you want to look at
   date <- "2012-01-01"

   What day did you pick? _____

   b. Turn that day into a day of the year using the following function
   doy_this <- as.numeric(strftime(date, format = "%j"))

   What is the day of year for your date?_____

   c. Find the profiles that were taken on that date
   cols_thisdate <- which(DoY_2012_ave < doy_this & DoY_2012_ave > (doy_this-1))

7. Check that there are profiles for that day, if length is not equal to 1 or more then pick another day
   length(cols_thisdate)

8. Now plot! Type:
   plot(x = mydata$TWoxy.mgL.2012[,cols_thisdate], y = mydata$TWpress.2012[,cols_thisdate], xlab = "Oxygen concentration (mg/L)", ylab = "Pressure (db)", type = "l")

   Add a title to your plot. Type:
   title(main = paste("Oxygen Profiles for",date))

Notice that you can customize this plot by changing the xlab, ylab, and main title.

You can also change the type to be equal to ‘p’ if you want to see points instead of a line (which it was when you typed ‘l’ (the letter, not the number) for each profile or ‘b’ if you want to see both points and a line for each profile

Part 2:

Now, instead of making a plot this way each time you want to make one, we have provided a function that contains all this code for you. It is basically the same code you just wrote, just hidden in a file so all you have to do is type in the function and specify what you want to plot. This lets you plot lots of different days very quickly and minimizes the number of typos that might cause you to want to pull your hair out!

1. To load the functions type:
2. source('oxygen.profiles.R')
3. Use the "Oxy_profile_1day" function to plot O2 and Chl profiles for a given day, like you just did above. Remember, the date must be from 2012 or 2105. Test out a few days, like below:

```
Oxy_profile_1day(date="2012-01-29",parameter = "O2")
Oxy_profile_1day(date="2015-12-05",parameter = "Chl")
```

4. Use the "O2_colorcontour" function to plot O2 for the whole year

```
O2_colorcontour("2012")
O2_colorcontour("2015")
```

5. What year will your group look at: _____

6. Make your oxygen color contour plot. What variable is on the x-axis? _____ Y-axis?_____ In color?_____

7. What are four major observations from looking at the whole year of oxygen data? (Think about overall what you observe in the surface vs deep water, summer vs winter, etc.
   - _____
   - _____
   - _____
   - _____
8. Where in the water column is the lowest oxygen? _____ Approximately what is that lowest oxygen concentration? _____

9. When in the year do you see the lowest oxygen near the surface (5 db)?
   _____

10. Where in the water column is the highest oxygen? _____
    Approximately what is that high oxygen concentration? _____

11. When in the year do you see the highest oxygen near the surface (5 db)?
    _____

12. Write down a few dates that you are interested in looking more closely at by creating a depth profile. Pick at least one day in the summertime and at least one day in some other season Remember that our goal is to better understand the oxygen levels in hood canal so that we can relate to when fish kills happen. Remember, fish are stressed at any oxygen concentration below 5 mg/L and can't survive below 2 mg/L:
    _____
    _____

13. Use the oxy_profile_1day function like we did in part 3 to plot profiles of oxygen and chlorophyll on those days. Note that some days don't have data, so you may have to try some days in the week or two around your days of interest you wrote down above. Also, note that 2015 had many days with no Chl data, so if you are a 2015 group, don't worry so much about getting those plots.

14. For each plot of oxygen, write down the year, day, depth of the maximum and what the maximum concentration is, depth of the minimum and what the minimum concentration is, and the depth where the oxygen concentration changes quickly. If there was chlorophyll data for your date, make a few observations about how much chlorophyll there was and what the depth profile looked like. Record your observations in the table on the next page.

Day	Maximum O2 concentration	Depth of maximum O2 concentration	Minimum O2 concentration	Depth of minimum O2 concentration	Depth of sharp decline in O2	Chlorophyll?

15. For the day of your lowest oxygen try to make plots of the days just before and after that date. Do they generally the same or different? _____
    If they look different, how do they differ?

    _____

    _____

    Would fish be stressed for oxygen on any of these days? Would you predict a fish kill on any of these days?

    _____

16. For the day of your highest oxygen try to make plots of the days just before and after that date. Do they generally the same or different? _____
    If they look different, how do they differ?

    _____

    _____

    Would fish be stressed for oxygen on any of these days? Would you predict a fish kill on any of these days?

    _____

Lesson 5

Objective: Collate the evidence and create a CER for the fish kill in the Hood Canal

NGSS:

1. MS-LS2-1 Ecosystems: Interactions, Energy, and Dynamics
   Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.
2. MS-LS2-3 Ecosystems: Interactions, Energy, and Dynamics
   Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.
3. MS-LS2-4 Ecosystems: Interactions, Energy, and Dynamics
   Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

Agenda

- Evidence Tracker (evidence tracker, pass back work, pass out Seattle times article 2 per table) (15)
- Observe First Model and compare to video (Watch Video- http://www.nanoos.org/products/hypoxia/estuarine_hypoxia.php)(5)
- Create a new conceptual model as a class (5)
- CER-- claim, evidence, reasoning (15)
- Evaluations of Program (5)

News article
http://www.seattletimes.com/seattle-news/fish-kill-risk-in-hood-canal/

Summary of Tasks

- *Evidence Tracker- Student will fill out their evidence tracker once their work from days 1-4 is passed back. Also, pass back their initial conceptual model and the attached Seattle Times article on fish kills in the Hood Canal. Provide the students with at least 10 minutes to complete this task. Encourage the students to be detailed.*
- *Compare! Ask the students to observe their first conceptual model. As they watch the NANOOS video on fish kills in the Hood Canal, ask the students to take notes in their evidence tracker.*
- *New Conceptual Model- The teacher will create a new conceptual model on the board with student input.*
- *CER- pass out the attached graphic organizer for the CER. Encourage the students to use their Evidence Tracker as they create their CER.*
- Each student will complete an evaluation of the program

Materials

News article

http://www.seattletimes.com/seattle-news/fish-kill-risk-in-hood-canal/

Evaluations

CER Rubric

Criteria	1	2	3
Claim	Claim does not respond to the question	Claim responds to the question but does not correctly explain the cause of the fish kill.	Claim correctly explains the cause of the fish kill.
Evidence	Cites evidence that is inappropriate to the claim or cites no evidence.	Cites evidence that may be insufficient but still connects to the claim.	Cites sufficient and appropriate evidence for the claim
Reasoning	No reasoning statement or inappropriate scientific principle.	May repeat the claim, question, or evidence. Attempts appropriate scientific concept but is unclear.	Uses 2 relevant and appropriate scientific principle.

Answer the following questions by circling a single number for each.

1. How included did you feel during the group work activities this week?
   I did not feel included 1 2 3 4 5 I felt very included

2. How much did you learn in the following activities?

   Hands-on Rotation Activity (Goldfish, Water Circulation, BTB)
   I did not learn much 1 2 3 4 5 I learned a lot

   Exploring NANOOS Website
   I did not learn much 1 2 3 4 5 I learned a lot

   Coding with R
   I did not learn much 1 2 3 4 5 I learned a lot

   Writing the CER paragraph
   I did not learn much 1 2 3 4 5 I learned a lot

3. Do you feel more/less comfortable with coding?
   I feel less comfortable 1 2 3 4 5 I feel more comfortable

4. Do you have any additional comments?
   _____
   _____
   _____

Answer the following questions by circling a single number for each.

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   I did not learn much 1 2 3 4 5 I learned a lot

   Writing the CER paragraph
   I did not learn much 1 2 3 4 5 I learned a lot

3. Do you feel more comfortable with coding?
   I feel less comfortable 1 2 3 4 5 I feel more comfortable

4. Do you have any additional comments?
   _____
   _____
   _____

Name_____ Class Period_____

Question: What killed the fish in the Hood Canal last September?

Claim - Answer the question. This should be a complete sentence.

Evidence - The evidence should be appropriate and sufficient to support your claim.

Evidence #1	**Evidence #2**	**Evidence #3**

Reasoning - Explain why the event occurred using your scientific knowledge and vocabulary terms.

Reasoning #1	**Reasoning #2**	**Reasoning #3**

Claim

_____

Evidence

Reasoning

Fish Kills Evidence Tracker

Process	Claim	Connection to Phenomena
Nutrients		
Source of Oxygen		
Fate of Oxygen		
Source of Carbon Dioxide		
Fate of Carbon Dioxide		
Water Circulation		

Fish-kill risk in Hood Canal http://www.seattletimes.com/seattle-news/fish-kill-risk-in-hood-canal/

By CHRISTOPHER DUNAGAN

HOOD CANAL — Severely low oxygen levels in southern Hood Canal have created conditions that could lead to a massive fish kill, experts say.

The trigger would be strong winds out of the south, which would bring low-oxygen waters to the surface, potentially killing thousands of fish in a short time, said Jan Newton, a University of Washington oceanographer. Newton observed similar conditions in September 2006, when thousands of dead fish washed up on shore.

“I’m not predicting a fish kill,” Newton stressed, “but things are setting up with the right ingredients.”

Based on 40 to 50 years of data, the oxygen content of Hood Canal south of Dabob Bay reached a record low at the end of August. A monitoring buoy at Hoodsport, Mason County, also shows a record-low level for this time of year.

The genesis of this year’s problem is a deep layer of low-oxygen water left over from last winter. For some reason, that water uncharacteristically failed to flush out.

Typically in the fall, a deep layer of dense, oxygenated water pushes in from the Pacific Ocean. That layer tends to come in under the less-dense water in Hood Canal, pushing low-oxygen waters upward. At the same time, low-oxygen waters from Belfair to Twanoh advance toward Hoodsport as rains wash into lower Hood Canal.

When strong south winds hit the Big Bend area near Hoodsport, the surface layers of Hood Canal are blown to the north, forcing low-oxygen waters up toward the surface. Fish will swim upward, trying to find oxygenated water, but they may have no place to go.

Such conditions do not always lead to a fish kill. In 2004 the deck was stacked with low-oxygen water, yet the lack of a strong south wind may have avoided a fish kill.

“What is clearly evident,” Newton wrote Tuesday in a condition report, “is that 2010 is a particularly low-oxygen year, even compared to historical records. … The summer 2010 oxygen values are the lowest or among the lowest seen in the records available for the months of June and July for years spanning 1952-1966 and 1998-2010, with the August 2010 data point the lowest on record.”

People living along the shore are urged to watch for dead sea life or other unusual conditions. Anyone

with such information may call the Spills Hotline, 800-424-8802.