ACTIVITY 10

The Jubilee Phenomenon

Estuary Principle

Ongoing research and monitoring is needed to increase our understanding of estuaries and to improve our ability to protect and sustain them.

Research Question

What is a “Jubilee” and what specific conditions must be present for a jubilee event to occur?

Introduction

During a jubilee event in Mobile Bay, you can walk along a beach and pick up dozens of flounder, pounds of shrimp, and bushels of crab! A jubilee can occur along a stretch of beach only a few hundreds of yards long or as long as 10 miles. They can last several hours or just a few minutes.

For many years people did not know why jubilees occurred. They only knew to watch for a very specific set of conditions. They knew from experience that the weather, tides, and time of day all had to be "just right" for a jubilee to happen. But why do jubilees occur? In this activity, students will examine the specific conditions that must be present to cause a jubilee event.

Table of Contents

This curriculum was developed and produced for:

The National Oceanic and Atmospheric Administration (NOAA) and The National Estuarine Research Reserve System (NERRS)

1305 East West Highway NORM/5, 10th Floor
Silver Spring, MD 20910

www.estuaries.noaa.gov

Financial support for the Estuaries 101 Middle School Curriculum was provided by the National Oceanic and Atmospheric Administration via grant NA06NOS4690196, administered through the Alabama Department of Conservation and Natural Resources, State Lands Division, Coastal Section and Weeks Bay National Estuarine Research Reserve. Support was also provided by the Baldwin County Board of Education.

TEACHER GUIDE

The Jubilee Phenomenon

Research Question

What is a "Jubilee" and what specific conditions must be present for a jubilee event to occur?

Content Objectives

Students will understand that:

- Water quality, tides, and weather within estuaries change and can change quickly.
- Water stratification in estuaries is caused by density differences related to salinity and temperature.
- When layers of water in estuaries are not sufficiently mixed, the bottom layer of water can become depleted in dissolved oxygen.
- Physical changes in water temperature, salinity, and dissolved oxygen can be observed and measured.
- Weather conditions, such as wind direction and speed, can be observed and measured.
- By monitoring water quality, tide, and weather conditions, researchers may predict likely times and locations for a jubilee to occur.

Exercises

Exercise 1: What is the Jubilee Phenomenon?

In this exercise, students use their inquiry skills to explore the jubilee phenomena found in Mobile Bay, Alabama. They will read a recent article about hypoxic events in Mobile Bay, examine a map of the bay, and work with an animated jubilee model and meet researchers to explore how and why jubilee events occur.

Exercise 2: Layered Water in the Estuary

In this exercise, students will perform a hands-on experiment with salinity-based density differences in water to better understand stratification of water in an estuary. This will help students better understand how the shoreward movement of oxygen-poor bottom waters in Mobile Bay forces bottom-dwelling (benthic) fish and crustaceans ashore causing a jubilee.

Exercise 3: When Did a Jubilee Occur?

In this exercise, students will take on the role of scientists and analyze several forms of scientific data to determine the exact day and time when a jubilee event most likely occurred. Once students make their determination, they will find out from scientists Mike Dardeau and Scott Phipps if they are correct.

Assessment Questions

Assessment questions based on content covered in *The Jubilee Phenomenon* can be downloaded on the web page for this activity in the Middle School Curriculum section of the Estuary Education website at estuaries.noaa.gov.

Vocabulary

Benthic – bottom-dwelling flora and fauna; from tiniest (bacteria) to medium-sized (nematode worms) to the highly visible (clams, polychaete worms)

Bottom current – water movements that result in the horizontal transport of water masses on bottom waters.

Datalogger – an instrument used to automatically measure and record environmental parameters such as temperature, salinity, and dissolved oxygen..

Density – the ratio of the mass of any substance to the volume occupied by it.

Diurnal tide – a tide in which there is only one high water and one low water each lunar day.

Dissolved oxygen – often referring to the oxygen content of water. The amount of oxygen dissolved in a given volume of water at a particular temperature and pressure.

Hypoxic – describes a condition of very low oxygen levels, in which the concentration of dissolved oxygen in the water column decreases to a level that can no longer support living aquatic organisms.

Neap tide – A tide in which the difference between high and low tide is the least. Neap tides occur twice a month when the Sun and Moon are at right angles to the Earth.

Offshore – direction away from the land toward the sea.

Offshore current – any current direction flowing away from the shore.

Oxygen – an element used in respiration, the process in which organisms release stored chemical energy.

Salinity – the concentration of salt dissolved in water.

Salt wedge estuary – estuary with a pronounced difference in salinity between surface and deeper water, the deeper waters being more saline.

Stratification – the layering of water due to differences in density of salt or water temperature.

Surface Current – takes place when water movements result in the horizontal transport of water masses on surface waters.

Tide – periodic rise and fall of ocean waters due to gravitational pull of sun and moon, and rotation of earth.

Taking It Further

Have students research the Dead Zone and what causes it? Students should compare and contrast a naturally-occurring hypoxic event with human-caused hypoxia such as the Dead Zone at the mouth of the Mississippi River.

EXERCISE 1

What is the Jubilee Phenomenon?

Estuary Concept

Researchers gather data within the Mobile Bay estuary that allows them to better understand the causes of the jubilee phenomenon.

Focus Question

Why do jubilees occur?

Performance Tasks

Students will:

- Read an article describing recent jubilee and hypoxic events in Mobile Bay.
- Examine a map of Mobile Bay, Alabama to identify the areas where researchers gather data and where jubilees frequently occur.
- View and interpret an animation of how jubilees occur to better understand the causes of a jubilee, including the effects of tides, time of day, wind direction, and levels of dissolved oxygen in the water.

Teacher Background

Jubilees are caused primarily by the upward movement of oxygen poor (hypoxic) bottom waters that force bottom-dwelling (benthic) fish and crustaceans ashore. Bottom water low in oxygen results from several coincidental circumstances that happen at the same time. Pockets of salty water accumulate in the deeper parts of Mobile Bay and stagnate during calm conditions in the summer. Then stratification, or the layering effect of water containing different levels of salt, occurs when dense salty Gulf water is overlain by less dense, freshwater from the rivers. When water is stratified or layered in this way, the layers don't get mixed, preventing the movement of oxygen from the air into the bottom water.

Water temperature also has an effect on the stratification of the water and is an important cause of a jubilee event. Warm water holds much less oxygen than cooler water. Mobile Bay is shallow (average depth is only 10 feet) and the water temperatures get very high in the summer months. This is the primary reason why jubilees only occur in summer.

Phytoplankton, (plant plankton), also plays an important role in the occurrences of jubilees. Plankton, along with other microorganisms form the base of the estuary food web that feeds many larger organisms in the bay. However, when an abundant supply of nutrients, such as animal wastes and fertilizers, get washed into the bay by rain, the phytoplankton population can increase drastically. At night, phytoplankton is unable to carry on photosynthesis and must actually take in tremendous quantities of dissolved oxygen from the water in order to sustain them. The more phytoplankton in the water, the more dissolved oxygen gets taken out of the near-surface water at night. This can cause the water near the surface to become more depleted of dissolved oxygen.

Overview

In this exercise, students use their inquiry skills to explore the jubilee phenomena found in Mobile Bay, Alabama. They will examine a map of the bay, read background material, and work with an animated jubilee model, all to explore how and why jubilee events occur.

Time Required

1 to 1½ hours

Normally, the worst oxygen-poor water remains at greater depths within Mobile Bay. However, if a gentle easterly wind creates a surface current, it will move the surface layer of water from east to west, from near shore to offshore. As a result, the oxygen-poor bottom water is moved in the other direction. It gets pushed shoreward by a rising or incoming tide from the Gulf of Mexico. (NOTE: Alabama and other states along the northern Gulf of Mexico experience diurnal tides. This means there are normally only one high and one low tide each day unless there is a neap tide. A neap tide takes place when there is very little difference between high and low tide (tidal range).

As this tide-driven, salty, low-oxygen water moves shoreward, sea creatures in its path are "driven" in front of it. Animals that are good swimmers can easily swim over the top of the advancing low-oxygen water mass, but the slower paced benthic organisms, such as crabs and flounder, must flee toward the shore (away from the low-oxygen water) as they try to get oxygen from the shallow water nearer the water's surface. If the water near the surface is also depleted in oxygen, the animals are in big trouble.

To summarize, these are the conditions needed for a jubilee event to occur:

- Jubilees usually occur just before or just after sunrise which is before phytoplankton start producing oxygen via photosynthesis.
- Jubilees only occur during the summer. They occur more frequently in June through September when water temperatures are highest.
- Jubilees occur most often when the tide is rising. when ocean water is entering Mobile Bay from the Gulf of Mexico. While most tides along the northern Gulf of Mexico are diurnal, occasionally jubilees also occur during a neap tide.
- The dissolved oxygen level in the water is around 2 parts per million (2 ppm) or below.
- Jubilees occur when there is a gentle easterly wind blowing the surface water away from the shore toward the middle of Mobile Bay.

When all of the above conditions are in place, a jubilee occurs.

Teacher Preparation

1. Review the above Teacher Background for this exercise.
2. View the Jubilee Animation on the web page for this activity on the Estuaries Education website at estuaries.noaa.gov. Students should view this animation after they have completed the Student Masters in this exercise. The animation will help students build their understanding of what a jubilee is before examining the scientific data about jubilee events presented in Exercise 3: *When Did a Jubilee Occur?*

You'll find multimedia and other resources on the web page for this activity in the Middle School Curriculum section of the Estuary Education website: http://estuaries.noaa.gov.

Procedure

1. Have your students read the introductory story to this activity on the web page for this activity on estuaries.noaa.gov. Talk about what happens in a Mobile Bay jubilee event. During a jubilee, hundreds of flounder, crabs, and other aquatic animals come up into the shallow waters along the eastern shoreline of Mobile Bay. People walking along the shoreline can pick up fish and crabs with their bare hands because the animals are "starved" for oxygen and too weak to escape. Jubilees are an easy way for local residents to fill their freezers with fresh seafood, compliments of Mother-Nature. For the folks who live along the bay, these events are such a cause for joyful celebration that they have come to be called jubilees.
2. Next, divide your students into five teams. Distribute copies of Student Master: *Deadly Oxygen Levels in Mobile Bay* to each team. Assign each team one section of the article. After the student teams read their assigned article section, they should discuss within their team what they learned about the relation of oxygen levels and the jubilee events at Mobile Bay. Have the five teams present their conclusions to the class.
3. When all five teams have presented their conclusions, ask the class to summarize what the problem is with having low levels of dissolved oxygen (DO) in Mobile Bay. Based on the article, your students should be able to answer that DO levels below 2 ppm are harmful or even deadly to aquatic organisms. When DO levels fall below 2 ppm, aquatic animals need to either leave the area with low oxygen or else they will die.
4. Since the jubilee phenomenon only occurs regularly in Mobile Bay, it has inspired many scientists to try to explain how and why the jubilees happen. Of course, people who live along the bay are less concerned with what causes the jubilees than knowing when and where the next one might occur. In order to predict when and where a jubilee will occur, scientists must first fully understand the causes of the jubilee event. Research and monitoring must be conducted to find the answers to why things happen.
5. Distribute copies of the remaining Student Masters to each student. Review the directions on the Student Master: *Come Study the Jubilee* with your students.
6. The first thing students will do is to examine Student Master: *Map of Mobile Bay*, Alabama to look at the unique features of Mobile Bay and locate where researchers collect the data they use. Be sure students locate the NOAA tide station, the water quality monitoring station (datalogger), and the weather station at Weeks Bay Reserve on the map.
7. When students are done with the map, show them the jubilee animation on the web page for this activity on estuaries.noaa.gov. Students will be using the animation to answer questions on Student Master: *Come Study the Jubilee*. The animation is short, so do not hesitate to show it multiple times.
8. Review the student's answers to the questions from Student Master: *Come Study the Jubilee*. Possible answers are provided below.
9. In conclusion, have students define what a jubilee is. Write a classroom description or list of how a jubilee event happens.

Materials

Per team

- Student Master: *Deadly Oxygen Levels in Mobile Bay*

Per student

- Student Master: *Come Study the Jubilee*
- Student Master: *Map of Mobile Bay, Alabama*
- Colored pencils

Questions and Possible Answers

Q1. Is the tide coming in or going out during a jubilee?

The tide is rising or coming in during a jubilee. A jubilee may also occur during a neap tide, but never when the tide is going out or falling.

Q2. In Mobile Bay, which way does the wind come from during a jubilee?

During a jubilee, the wind is easterly. The wind is blowing from east to west. The wind is blowing in the opposite direction of tidal movement.

Q3. At what time of day does the jubilee occur?

The jubilee occurs early in the morning, around sunrise. .

Q4. Is the dissolved oxygen level in the water high or low during a jubilee?

The dissolved oxygen level in the water is dangerously low during a jubilee.

Q5. What happens to the bottom-dwelling animals during a jubilee event?

The bottom dwelling animals are forced to move away from the moving wedge of low-oxygen water. This moves them toward the shallow waters along the shore.

STUDENT MASTER

Come Study the Jubilee

It's a jubilee! Each summer, Alabama residents who live near Mobile Bay eagerly await jubilee events. They are excited by the prospect of gigging hundreds of flounder or catching tubs of blue crabs in just a few hours as these organisms literally come ashore. There is lots of fun and good food to be had by all!

Although jubilee events may occur in other areas of the world, Mobile Bay is probably the only body of water on Earth where this phenomenon occurs regularly each summer and where jubilees are fairly predictable. But to do that, you have to understand the unique combination of conditions that cause a jubilee. For that, you should join Mike and Scott on their boat.

On a hot summer morning, Mike Dardeau of Dauphin Island Sea Lab and Scott Phipps, Research Coordinator for Weeks Bay Reserve, drive their boat across the still waters of Mobile Bay. They are on their way to a datalogger location. At the monitoring site, they will download water quality data from the datalogger to their computer and take the data back to the lab at Weeks Bay Reserve. They will also gather data about wind speed and direction from the weather station located at the Reserve. And they will also have data about the local tide times and heights from the NOAA tide station and the Alabama Department of Marine Resources tide calendar.

But before you can join Mike and Scott in looking at the data, you should probably start out with the basics. Where do the jubilees occur in Mobile Bay? What causes jubilees?

Questions 1: Where do the jubilees occur ?

Examine the Student Master: Map of Mobile Bay, Alabama. Follow the directions on the Student Master to find the location of Mobile Bay, the datalogger, Weeks Bay Reserve, and the general locations where jubilees occur along the shores of Mobile Bay.

Question 2: What causes jubilees?

You already have some idea about the connection of dissolved oxygen to jubilee events from reading the article in Student Master: Deadly Oxygen Levels in Mobile Bay. Now watch the jubilee animation on the web page for this activity, use the Student Master Viewing Guide Jubilee Animation and answer the following questions:

Q1. Is the tide coming in or going out during a jubilee?

Q2. In Mobile Bay, which way does the wind come from during a jubilee?

Q3. At what time of day does the jubilee occur?

Q4. Is the dissolved oxygen level in the water high or low during a jubilee?

Q5. What happens to the bottom-dwelling animals during a jubilee event?

STUDENT MASTER

Deadly Oxygen Levels in Mobile Bay

Scientists report unusually low levels of oxygen in Mobile Bay waters

Article by Ben Raines, Press-Register, Mobile AL
Published Tuesday, September 06, 2011

Team 1

MOBILE, Alabama -- For more than a week in August, the water in Mobile Bay contained some of the lowest levels of oxygen on record.

The amount of oxygen dissolved in the bay is of critical importance to everything that lives in the water. When dissolved oxygen levels dip below 4 parts per million, aquatic creatures begin to suffer. When levels dip below 2 parts per million, marine animals either leave an area or die.

Oxygen levels below the critical 2 parts per million threshold were recorded at a meter attached to Middle Bay Lighthouse on Aug. 18 and stayed below that level for most of the next five days. In fact, oxygen levels were below 0.5 parts per million for several days during that time, well into the lethal range. Oxygen meters located in Bon Secour and at Katrina Cut on the Mississippi Sound likewise registered deadly levels for days at a time, suggesting a widespread problem.

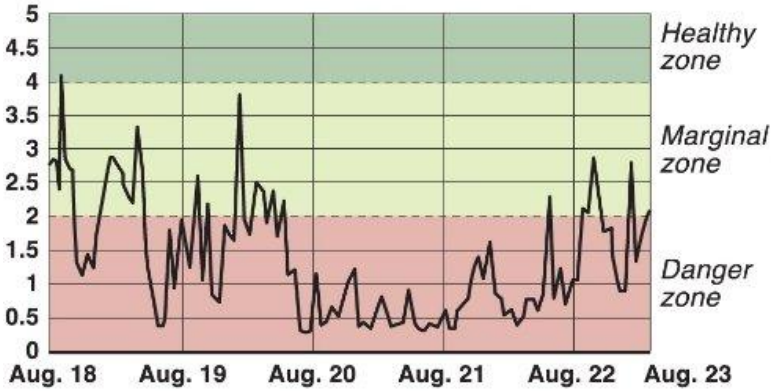
"That was the lowest (dissolved oxygen level) I've seen," said George Crozier, director of the Dauphin Island Sea Lab. "I've never seen levels below 1 for so long."

Oxygen levels are controlled by environmental factors. Wind, waves and tidal currents all help mix oxygen into the water column. Decaying organic matter sucks oxygen out of the water, while high water temperatures reduce the amount of oxygen water can hold. In addition, in estuaries such as Mobile Bay, a layer of freshwater often floats on top of the saltwater, preventing oxygen from mixing with water closest to the bottom.

Deadly 02 levels in parts of Mobile Bay

Oxygen levels in Mobile Bay took a steep dive in August, dropping below the level marine life needs to survive in parts of Mobile Bay and the Mississippi Sound. Levels below 2 parts per million are lethal. The meter on Middle Bay Lighthouse is 9 feet underwater. While oxygen levels at depth can be deadly, fish, crabs and other creatures can swim to the surface to escape low oxygen areas.

Oxygen level results, in parts per million, from August 18-22, 2011



Sources: Mobile Bay National Estuary Program, Dauphin Island Sea Lab

Press-Register graphic

Team 2

Heavy rainfall across Alabama this spring and summer pushed large amounts of freshwater carrying pollutants, such as fertilizers and animal waste — which scientists refer to as nutrients — into the bay. The influx sets the stage for the creation of dead zones in Mobile Bay, scientists said.

The heavy flows in the state's rivers mirrored the record flows coming from the Mississippi River this year. That Mississippi water — laden with nitrogen-rich runoff from farms, golf courses, and sewage plants — is blamed for the largest dead zone ever recorded in the Gulf of Mexico. The nitrogen fuels the growth of algae, which then dies and settles to the seafloor, where it consumes oxygen as it decays.

Scientists say the same brew of manmade pollutants comes down Alabama's rivers and causes a similar but smaller dead zone in Mobile Bay every summer. The data from this summer suggest the zone may be more expansive than in years past.

"All the nutrients delivered from the watershed during the springtime, that's a big part," said John Valentine, who has been named the next director of the Sea Lab. "Add in the really hot summer and the absence of wind, along with insufficient exchange of water, and there you go — low oxygen."

Those low oxygen dead zones are the key to the jubilee phenomenon in Mobile Bay. Fairhope experienced jubilees five days in a row during August's low oxygen episode.

Jubilees, which are common nowhere in the world except Mobile Bay, are extreme examples of what happens when oxygen levels drop below what is required to support marine life.

Team 3

Jubilees typically occur on still nights in the heat of the summer when there is almost no tidal movement. Fish, crabs, rays, eels, shrimp and other creatures are literally chased to shore by a plug of water so low in oxygen that it is lethal.

The animals congregate in the barest shallows, where oxygen levels are slightly higher.

"Animals are trying to move out of the low oxygen areas. The jubilees just represent animals that made a bad choice," said Valentine. "Those animals made a right turn instead of a left turn. They got caught by the low oxygen area and ended up on the dinner table."

People living around Mobile Bay have been taking advantage of sea creatures driven to shore by low oxygen for at least 200 years. A key question today is whether jubilees are becoming more common because of man's impact on the ecosystem.

Team 4

"There are no data that map (low oxygen in Mobile Bay) consistently. You have to be careful with historical reconstructions when you don't have data," Valentine said. "The hardest thing to do is to tease apart the things that are the result of Mother Nature versus the things that are the result of man."

Last summer, a number of jubilees were reported on the western side of Mobile Bay, an extremely rare, if not unprecedented, development. This year, jubilee conditions have been reported on Gulf beaches between Gulf Shores and Fort Morgan.

"We had crabs and skates, kind of like a jubilee event coming in toward the beach around Little Lagoon Pass," said Chris Blankenship, director of the Alabama Division of Marine Resources. He blamed the problem on low oxygen conditions along the shoreline and described it as unusual.

While the Gulf's dead zone is largely the result of huge blooms of algae, which die and consume oxygen as they decay, the low levels seen in the bay result from a combination of algae blooms and separation of water into the fresh and salt layers.

"With the temperatures the way they are, when we don't have a big, big tidal influx, we see the oxygen disappear," said John Dindo, a biologist with the Sea Lab.

Team 5

The scientists all blamed hot, windless days coupled with a period of weak tides between Aug. 15 and 20 as contributing factors. With no tidal action and no wind, there was little mixing of water on the bottom of the bay with the more oxygenated water on the surface.

"It was so hot. You'd step outside in the morning and it was so still there just wasn't a breath of air," Crozier said.

Dindo said he noted large numbers of blue crabs swimming on the surface around Dauphin Island during the low oxygen spell. Such behavior occurs in response to depleted oxygen levels in the lower part of the water column, where the crabs typically live.

"With crabs, it would be illogical for them to swim on the surface in the daytime, because of predators. They are vulnerable on the surface," said Valentine. "They are just trying to grab a breath of oxygen up there because they don't have a choice."

Local crabbers have reported pulling up traps full of dead crabs. The crabs swim into the traps while foraging when oxygen levels are good, then are unable to leave the area when oxygen drops.

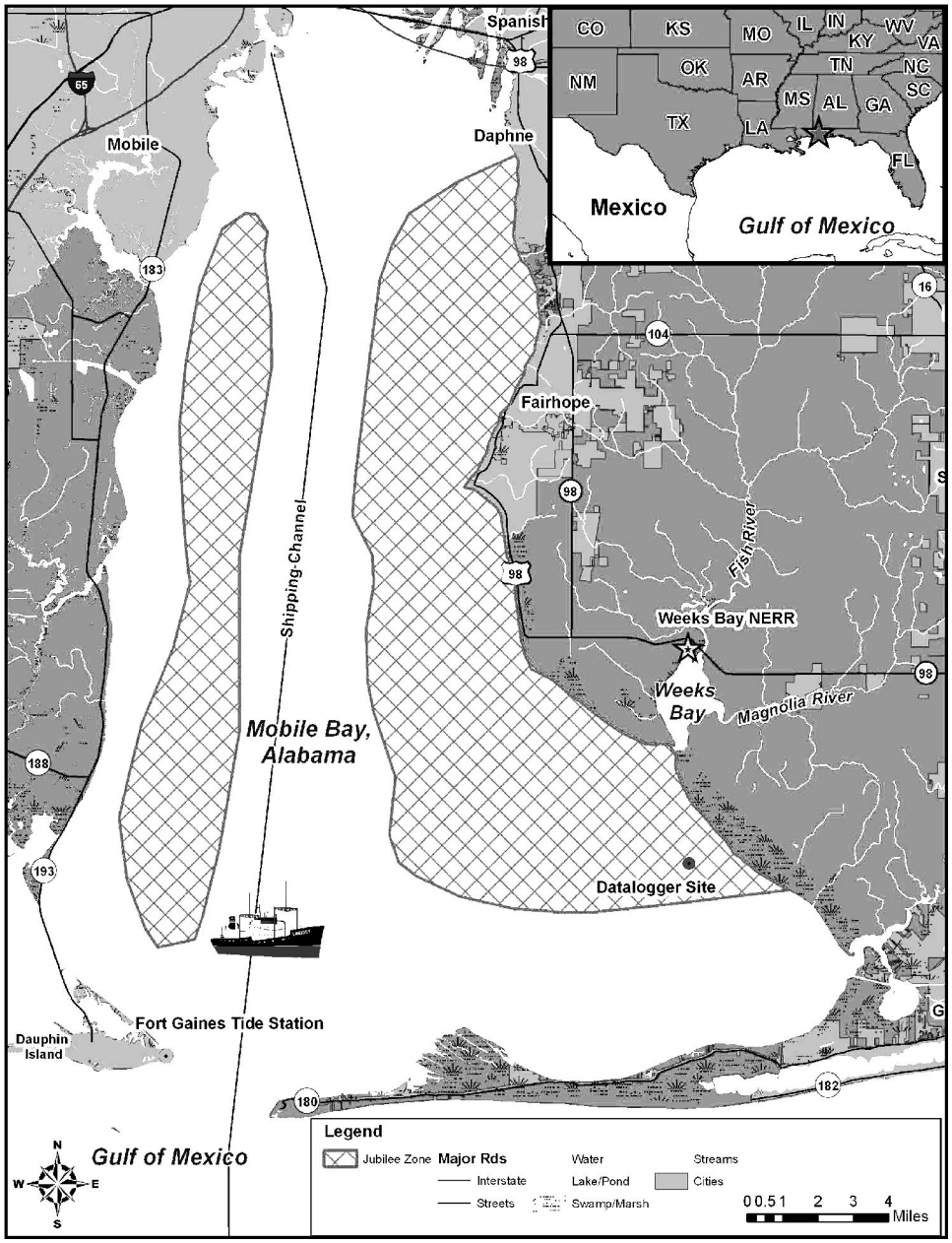
"The good news, it's all going to change. The first time we get a big storm that churns all the water up and mixes everything again, it will all be over," Dindo said.

STUDENT MASTER

Map of Mobile Bay, Alabama

Use colored pencils to complete the following:

1. Locate the datalogger site and circle the location with a purple colored pencil. Researchers collect data here.
2. Write directions from the datalogger site to Weeks Bay Reserve. Remember to use the map legend in the lower right corner and the compass rose in the lower left corner.
3. Write directions from the datalogger site to the tide station on Dauphin Island.
4. Find the possible jubilee locations on the map and outline them using an orange colored pencil.
5. Use a blue colored pencil and put a check at the mouth of Mobile Bay.
6. Use a green colored pencil to put Xs where the freshwater flows into Mobile Bay from all the rivers. Do not forget the river delta at the very top of the map.
7. Put a circle around Weeks Bay with a blue pencil.



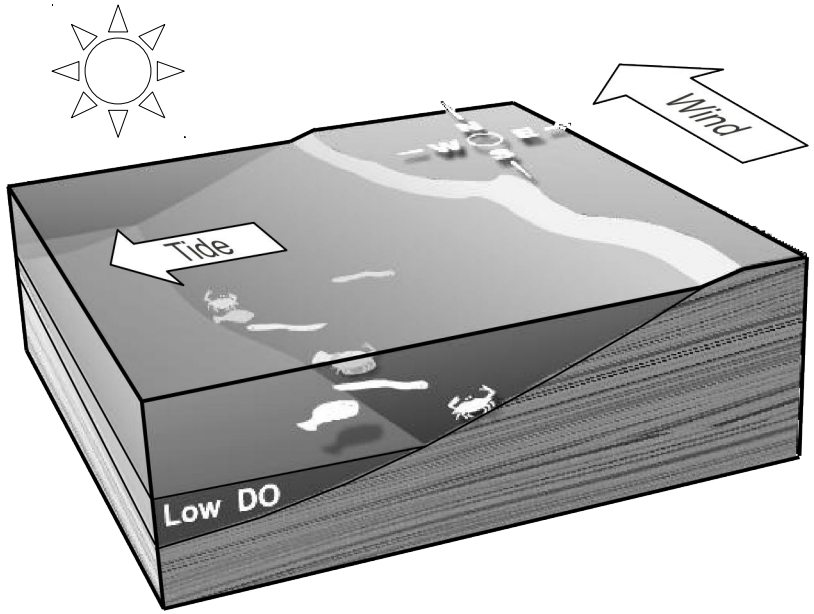
Bonus Mystery Question: After reading the article Deadly Oxygen Levels in Mobile Bay, why do you think jubilee events happened on the west side of Mobile Bay when they usually happen on the east side of the bay?

STUDENT MASTER

Viewing Guide: Jubilee Animation

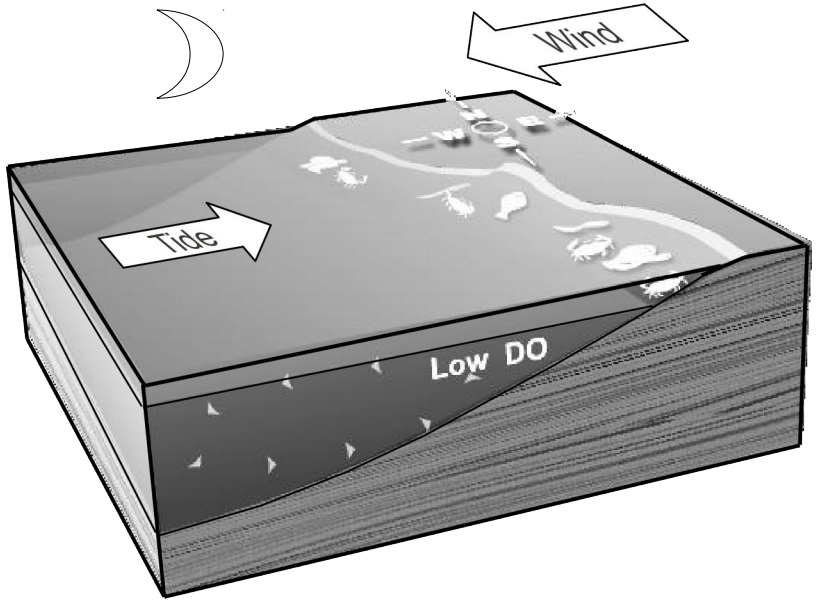
Watch the Jubilee Animation on Estuary Education website once. Then watch it again and follow the directions below. Use colored pencils to shade the two diagrams below following the instructions provided. Then answer the questions.

Figure 1



- Wind is from the south. Color the wind arrow green.
- The sun is up. Color the sun yellow.
- The tide is falling (outgoing). Color the tide arrow red.
- A wedge of deep water containing low amounts of dissolved oxygen moves away from shore.
- Aquatic animals are on the bottom of the shallow water where they belong. Color the animals light blue.

Figure 2



- Wind is from the east. Color the wind arrow green.
- The moon is up indicating that it is nighttime. Color the moon black.
- The tide is rising (incoming). Color the tide arrow red
- A wedge of water containing low amounts of dissolved oxygen moves toward the shore.
- Aquatic animals move onto the beach. Color the animals light blue.

EXERCISE 2

Layered Water in the Estuary

Estuary Concept

Estuaries are constantly shaped by water flowing from the uplands as well as by tidal cycles moving and mixing fresh water and salt water in and out of the estuary.

Focus Question

How do differences in physical properties lead to layering of water within an estuary?

Performance Tasks

Students will:

- Perform an experiment to see whether two layers of water can remain separated because of differences in their salinity.

Overview

Water in estuaries is often stratified or made up of layers. Each water layer has specific properties that can be measured, such as salinity, temperature, dissolved oxygen, and depth. In this exercise, students will focus on the salinity of these layers.

Time Required

One 45-minute class session

Teacher Background

Jubilees are caused primarily by the upward movement of salty, oxygen-poor, bottom water. This water movement forces bottom-dwelling (benthic) fish and crustaceans to move ashore as they try to escape the oxygen-poor water. This bottom water that is low in oxygen results from several circumstances that coincidentally happen at the same time.

In this exercise, students will be asked to examine one of these circumstances: the process of salinity stratification within Mobile Bay. Salinity stratification is the layering of water due to differences in salt content. The greater the water's density, the more likely it is to sink to the bottom. Less dense, less salty water layers will be found above the denser, saltier water layers. Fresh water is the least dense and should normally be found at the top of a stratified water column. This layering effect happens naturally in Mobile Bay where saltier, denser water from the Gulf of Mexico is overlain by lighter, fresh water entering the bay via rivers and streams. Stratification often prevents movement of oxygen from the air into the saltier bottom water. The dissolved oxygen gets "stuck" in the top, fresh water layer.

Teacher Preparation

1. Prepare for the demonstration by filling two pitchers with room temperature water. In the first pitcher, add 6 tablespoons of salt for each 100 milliliters (ml) of water in the pitcher. Mix the water until the salt has dissolved. Do not add any salt to the second pitcher of water. Add a few drops of blue food coloring to the first pitcher with the salt water and a few drops of red food coloring to the second pitcher with the fresh water. The color of the water in each pitcher needs to be dark enough for students to see a distinct color difference between the two types of water. Label the two pitchers "Salt water" and "Fresh water."

2. Gather materials the students will need to perform the experiment described in Student Master: *Stratification in the Estuary.*
3. Make copies of Student Master: *Stratification in the Estuary.*

Procedure

1. Divide students into teams of two to four students per team.
2. Distribute one copy of Student Master: *Layered Water in the Estuary* to each team.
3. Have students read both the Procedures and Questions sections of the Student Master before starting the experiment. Answer any questions your students may have before work begins.
4. Students will follow the instructions on the Student Master to do the experiment.
5. When teams have finished the experiment and cleaned up, have students answer the questions on the Student Master. Possible answers to the questions are provided below.

Materials

Per class

- 2 pitchers of room-temperature water
- Salt
- 2 colors of food coloring (red and blue)
- Beaker or measuring cup
- Spoon or stirring rod

Per team

- Student Master: *Layered Water in the Estuary*
- Clear graduated cylinder, beaker, or jar (at least 10 cm tall)
- 2 additional beakers
- Pipette or dropper
- 6 to 10 sesame seeds
- Drinking straw
- Lab apron(s)

Questions and Possible Answers

Q1. Did the two layers of water remain mostly separate? Why do you think the two layers stayed separate?

Yes. The salt water is denser than the fresh water. Less dense materials float on denser materials. The fresh water "floats" above the salt water because the fresh water is less dense than the salt water.

Q2. How do the two layers in this stratified water column model relate to the water in Mobile Bay?

The bottom layer in the model represents the salty ocean water. The top layer in the model represents the fresh water entering the bay from the watershed. Without something to mix the two layers, the fresh water layer is found in a layer above the salt water layer within Mobile Bay.

Q3. Describe what happened to the water layers when you blew gently across the water's surface.

The surface of the top water layer moves away from the straw. The "wind" blows the water to the opposite side. As the fresh water moves away from the side of the container nearest the wind, some of the salt water is pulled up along the inside of the container and starts to mix with the freshwater layer.

Q4. The sesame seeds represent the organisms that live in the water. Did the very bottom organisms move to another level of water? Why or why not?

The sesame seeds at the bottom of the container are locked into place under the salty water. The wind did not affect the salt water layer at that depth.

Q5. Did the organisms on the water's surface move up or down? Why do you think this is so?

The sesame seeds moved to a lower level in the fresh water layer, but did not move down into the salt water layer.

Q6. Why is it important for Mike and Scott to know about stratification of water layers in Mobile Bay when studying jubilee events?

A jubilee event is directly related to the water in Mobile Bay being in layers. When a wedge of oxygen-poor bottom water moves toward the shore, it causes benthic organisms, such as crabs and flounders, to run away from the wedge and toward the shore.

STUDENT MASTER

Layered Water in the Estuary

The water in Mobile Bay, while shallow, tends to be in layers. Fresh water coming from the rivers does not contain a lot of salt. That means the fresh water is less dense than the saltier ocean water from the Gulf or even the brackish water already in the estuary. Less dense liquids float on top of denser liquids. Without mixing, bodies of water become stratified, or layered, due to density differences. Salinity is one factor influencing water density. Water temperature is another. You would expect to find the warmer water layer above the colder water layer.

Follow the directions to build a stratified (layered) water column based on density differences due to differences in water salinity.

Procedure

1. Gather your materials. Don't forget a lab apron! The water in this exercise contains food coloring that can stain your clothes.
2. You will have two beakers or jars of the same size. Fill one beaker half full of blue water from the pitcher provided by your teacher. Half fill the other beaker with the red water. The blue water in the pitcher labeled "Salt water" represents the salty water located along the bottom of Mobile Bay. Your teacher has actually added salt to this water. The red water in the pitcher labeled "Fresh water" represents the fresh, surface water coming into Mobile Bay from the watershed via the river.
3. Now take a clean cylinder, beaker, or jar and drop five sesame seeds into the bottom.
4. Use a pipette or dropper to gently add salt water (blue) to the cylinder or jar until it reaches the height of 2 cm.
5. Rinse your pipette or dropper.
6. Add five more sesame seeds to the top on the blue water.
7. Now use the pipette or dropper to gently add fresh water (red) to the cylinder or jar. Go slowly, trying to make sure to not disturb the layer of salt water already in the container. You might find dribbling the fresh water down along the inside surface of the cylinder or jar will work best. Add enough fresh water to form a second layer, also 2 cm in height.
8. Now add five sesame seeds to the top surface of the fresh water layer.
9. You should have a water column with two layers: a salt water layer on the bottom and a fresh water layer on the top. If you do not, start over!
10. Use a straw to blow gently across the water's surface. Do not blow directly down on the water! Blow at an angle of 45 degrees or less. What happens to the seeds? What happens to the top layer of water?
11. Return any unused blue or red water to the pitchers. Then clean up following your teacher's instructions.
12. Answer the questions on the next page.

Questions

Q1. Did the two layers of water remain mostly separate? Why do you think the two layers stayed separate?

Q2. How do the two layers in this stratified water column model relate to the water in Mobile Bay?

Q3. Describe what happened to the water layers when you blew gently across the water's surface.

Q4. The sesame seeds represent the organisms that live in the water. Did the very bottom organisms move to another level of water? Why or why not?

Q5. Did the organisms on the water's surface move up or down? Why do you think this is so?

Q6. Why is it important for Mike and Scott to know about stratification of water layers in Mobile Bay when studying jubilee events?

EXERCISE 3

When Did a Jubilee Occur?

Estuary Concept

Researchers use tide data, wind direction, dissolved oxygen, and temperature data to select areas that are suitable for estuary research.

Focus Question

What data is needed to determine when a jubilee event occurred?

Performance Tasks

Students will:

- Join researchers in determining when a jubilee event occurred in Mobile Bay by analyzing tide, weather, and water quality data for three different days during the summer of 2011.

Teacher Background

Water Quality (dissolved oxygen)

One measure of water quality is dissolved oxygen (DO). Oxygen enters the water from the air at the water's surface. Fresh water pouring into the estuary from rivers upstream contains dissolved oxygen. And more oxygen is released into the water by the phytoplankton living in the water. The dissolved oxygen supports aquatic life, both plant and animal. A healthy range of dissolved oxygen for aquatic animals is about 4-5 parts per million (ppm). DO levels between 2 ppm and 4 ppm will cause aquatic organisms to be stressed. In the case of a jubilee, the water becomes very oxygen poor on both the surface and bottom layers. The DO drops to 0 to 2 ppm. DO levels below 2 ppm are lethal to organisms that cannot move away to find more oxygen.

Tides

A slow moving incoming or rising tide is necessary to create a jubilee event. A rising tide pushes salt water from the Gulf of Mexico into the estuary. Areas along the northern Gulf of Mexico coast have diurnal tides, meaning there is only one high tide and one low tide each day. The tidal range between high and low tide is only about 2 feet. This tidal range is very small compared to other estuaries around the world. Occasionally jubilee events in Mobile Bay occur during neap tides. Neap tides are tides that havevery little difference between the high and low water levels.

Water Temperature

Temperature is another important parameter related to the jubilees. Temperature is a driving factor in the chemical and biological processes that determine how well an aquatic environment can support life. In the case of a jubilee event, the

Overview

Monitoring stations provide researchers with data that allows them to better understand changes taking place in an estuary. This data is necessary for understanding the causes of the jubilee phenomenon. In this exercise, students join researchers in examining real water quality (dissolved oxygen), tide, and weather (wind) data to find the short-term changes associated with jubilee events. Students then use the collected data from the Bon Secour monitoring station site to analyze three dates (June 25th, August 5th, and August 25th) to see if one or more of the days met the conditions needed for a jubilee event to occur.

Time Required

One 45-minute class session

warm water present in Mobile Bay during the summer helps create conditions that lower the amount of dissolved oxygen. Warmer water holds less dissolved oxygen. The range for high surface water temperatures are 70 degrees F to above 90 degrees F in the summer.

Weather

Wind is air moving from an area of high pressure to an area of low pressure. Wind is caused by the Sun's energy, warming different parts of Earth's surface at different rates. Wind can come from the North, South, East or West. Winds are named for the direction from which they appear to originate. For example, an easterly wind moves from the east to the west.

An easterly wind of 2 to 5 miles per hour is needed for a jubilee event to occur. The wind needs to be strong enough to push surface water away from the eastern shore of Mobile Bay, but not strong enough to mix the surface and bottom waters together.

Teacher Preparation

1. Review the Teacher Background section above.
2. Review Student Master: *When Did a Jubilee Occur?* Familiarize yourself with the graphs on the Student Master prior to the activity so you can answer any questions that might come up.
3. If you feel students will benefit from the extra help, be prepared to project the August 25th graph from the Student Master. Then use the Teacher Master: How to Read the Graphs to walk your students through the data found on the graph.

Procedure

1. Explain to students that they are being asked to join researchers as they analyze archived water quality, tide, and weather data from monitoring stations located around Mobile Bay. Remind students that they, just like researchers, can use data to get answers to questions. Explain to your students that they will be examining water quality, weather, and tide data for three different dates in the summer of 2011: June 25th, August 5th, and August 25th to see if the data supports a jubilee having occurred on one or more of those three days.
2. Next, give each student a copy of the Student Master: *When Did a Jubilee Occur?* Review the directions found on the Student Master. There is one graph for each date. The students must analyze data from all three graphs to see if a jubilee event occurred on any of the three days.
3. If you feel your students need help with interpreting the graphs, you may project the Teacher Master: *How to Read a Graph* and the August 25th graph on a board, wall, or Smart Board. Explain the key features of the graphs in this exercise. Point out that each graph displays three types of data: Dissolved Oxygen, Tide Height, and Wind Direction. Show your students where to find each type of data on the graph, which vertical scale goes with which line, and how to read the wind direction icons.

Materials

Per student

- Student Master: *When Did a Jubilee Occur?*

4. Go over the Data Log on the Student Master to make sure your students understand what important data they need to record about each of the dates.
5. Students now follow directions on the Student Master to complete the exercise. Bring students together to hear their analyses of which days, if any, had jubilee events. When everyone has presented, read the class the solution provided below.

Questions and Possible Answers

Students' completed data charts for Bon Secour Station should contain the following information:

Date	What was the time range of the lowest dissolved oxygen levels on this day?	Was the dissolved oxygen (DO) level near or below 2 ppm on this day?	Was the tide rising (water entering the bay) or falling (water leaving the bay) near dawn on this day?	Was the wind easterly (blowing from the east) near dawn on this day?
June 25, 2011	6am to 10am	Yes, DO is near or below 1ppm	Tide rising	Yes, wind was out of the east/ northeast around 6am
August 5, 2011	12 noon to 10 pm	Yes, DO is near 0 ppm the entire day	Tide falling	No, the wind did not switch to easterly until well after dawn, about 9 am
August 25, 2011	4 am to 9 am	Yes, DO is near or below 1 ppm	Tide rising	No, wind mostly out of west and north around dawn

Have students present their conclusions before reading them the following answer:

> Here is what Mike Dardeau and Scott Phipps wanted to tell you about the data and days you studied:
>
> A jubilee event did not occur on either August 5th or August 25th. Neither day meets all of the conditions needed for a jubilee to occur. August 5 had all of the conditions for a jubilee except that the tide was falling at dawn instead of rising. The dissolved oxygen was low, but the water was moving in the wrong direction. August 25 met all of the jubilee conditions except that the wind was not out of the east when the dissolved oxygen was low at dawn.
>
> A jubilee event **did** occur on June 25, 2011! All of the conditions for a jubilee were met. The wind was blowing out of the east just before the sun came up at 6 a.m. A 1 foot tide was coming into Mobile Bay at that time. And the dissolved oxygen level was just below 1 ppm, which is in the danger zone for marine life.

TEACHER MASTER

How to Read the Graphs

Use the following to explain key features of the three graphs used by students in this exercise.

1. Project the August 25th graph on a board, wall or Smart Board.
2. The graph title is the first thing you should look at. The title at the top of the page tells you the name of the monitoring station (Bon Secour), the types of data that are shown on the graph, and the date (August 25, 2011).
3. The title says that the graph is displaying three types of data for August 25, 2011: 1) dissolved oxygen; 2) tide height; and 3) wind direction. Most of the time, you might only see a graph with one type of data displayed over time. On these graphs, you will see three types of data displayed over time.
4. What is the horizontal axis of the graph? All three data types are displayed over time. So the horizontal axis of this graph is time. The 24 hour day is divided into half hour units and displayed along the horizontal axis, running from midnight to midnight.
5. The vertical axis along the left side of the graph is for dissolved oxygen, which is measured in parts per million (ppm). The thick graph line is labeled as dissolved oxygen.
6. There is an additional graph feature to allow you to interpret the significance of the dissolved oxygen levels. There are three horizontal shaded bands running across the graph. These zones display the impact of different dissolved oxygen levels on the health of aquatic organisms that live in the water:

   Healthy Range: 4-5 ppm
   Marginal Range: 2-4 ppm
   Danger Range: 0-2 ppm

   If the dissolved oxygen line is within the danger range, then water at Bon Secour would not be healthy for aquatic organisms at that time on that day.
7. The vertical axis along the right side of the graph is for tide height, which is measured in feet. The thin graph line is labeled as tide height.
8. Below the graph are wind direction icons. The sample interval is every two hours during the day. The arrow points in the direction the wind is blowing. An easterly wind is defined as blowing from the east toward the west. So the wind direction icon for an easterly wind should point toward the left.

STUDENT MASTER

When Did a Jubilee Occur?

Scott Phipps and Mike Dardeau with a datalogger at Bon Secour monitoring station

Tidal datum station, Weeks Bay Reserve

Weather station, Weeks bay Reserve

Scientists Mike Dardeau, of Dauphin Island Sea Lab and Scott Phipps, Research Coordinator for Weeks Bay Reserve, want you to think about the following: "If you weren't there along the shores of Mobile Bay to see the fish and crabs coming onshore during a jubilee, what kind of data would you need to examine to identify when jubilee event occurred?"

What do you think? If you understand the conditions that cause a jubilee and if you have data about those conditions on a specific date, you should be able to say whether or not a jubilee occurred. Let's see if that's true!

Procedure

1. Mike and Scott have provided you with Mobile Bay datalogger data for three days in the summer of 2011. The graphs, one for each day, show dissolved oxygen, tide height, and wind direction.
2. Look at each graph. What does the dissolved oxygen level graph show happening on that day? When was the tide rising and falling on that day? In which direction was the wind blowing?
3. As you examine the three graphs, keep a record of your findings in the Data Log. You will need the data you record to either support or disprove which dates met the conditions for the occurrence of a jubilee event.
4. Once you have examined all three graphs and filled in the Data Log, use the Jubilee Conditions Checklist to help you draw your conclusions about which day or days jubilees occurred. Remember, a jubilee should only occur when all of the conditions on the checklist were present in Mobile Bay.

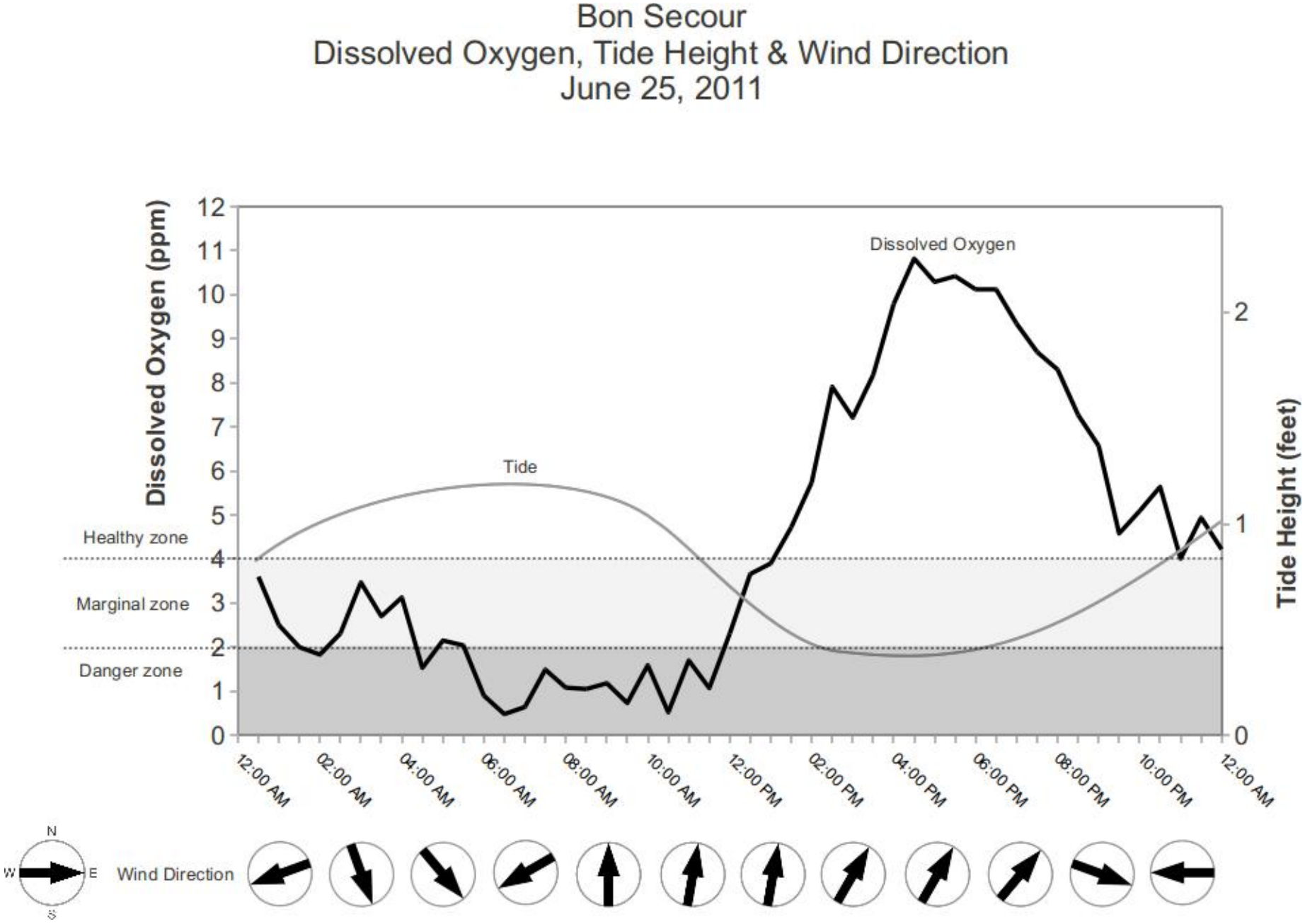
Jubilee Conditions Checklist

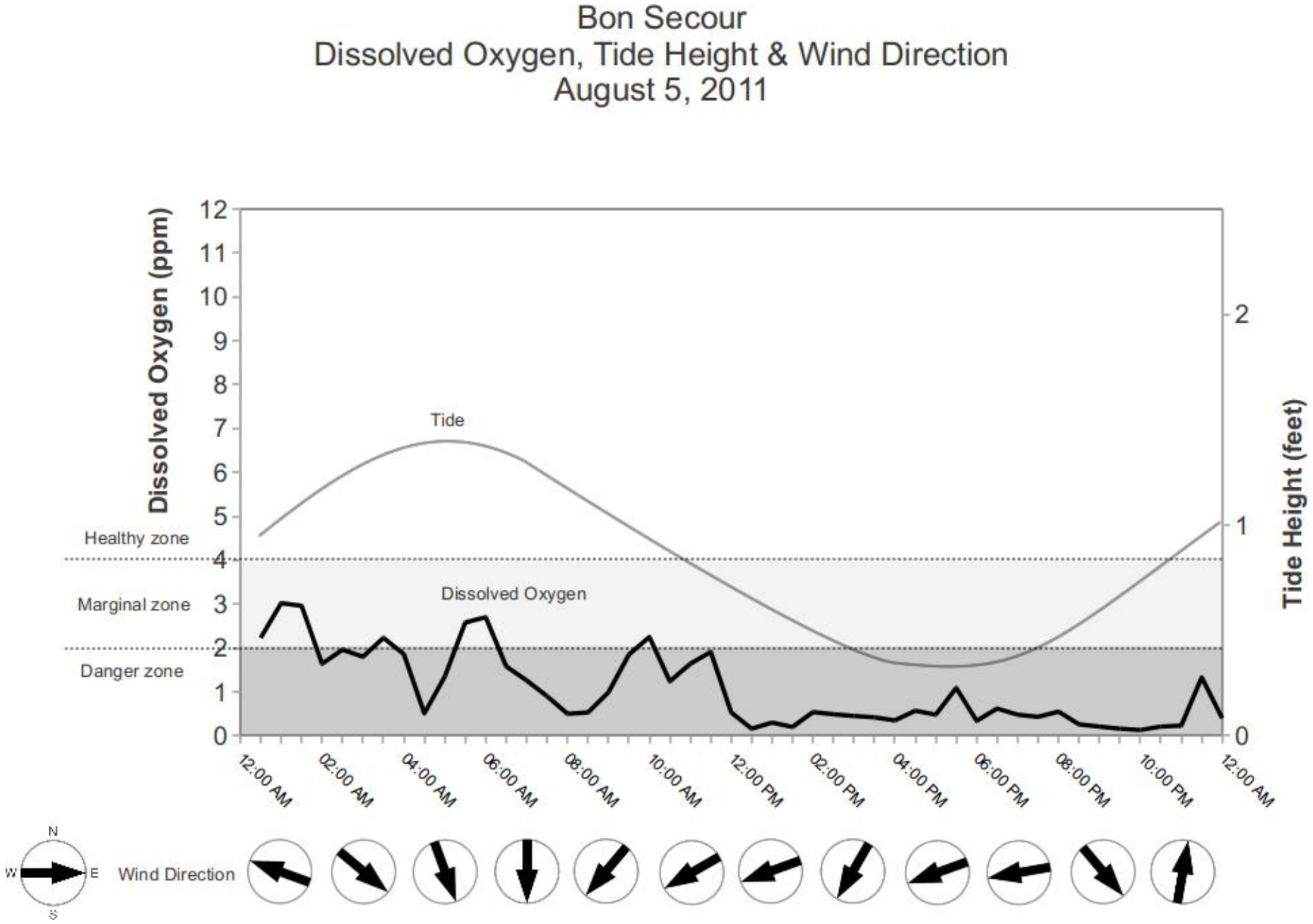
- ✔ It is summer. The water temperature in summer is very warm.
- ✔ It is very early morning and the sun is still down or just rising.
- ✔ Because of the warm water and the time of day, dissolved oxygen levels in the water are very low.
- ✔ The wind is easterly. The wind is blowing gently from the east and moving the fresher surface water away from the shore and into the middle of the bay.
- ✔ The tide is rising. Water is coming in from the Gulf of Mexico, but has very little tidal movement.

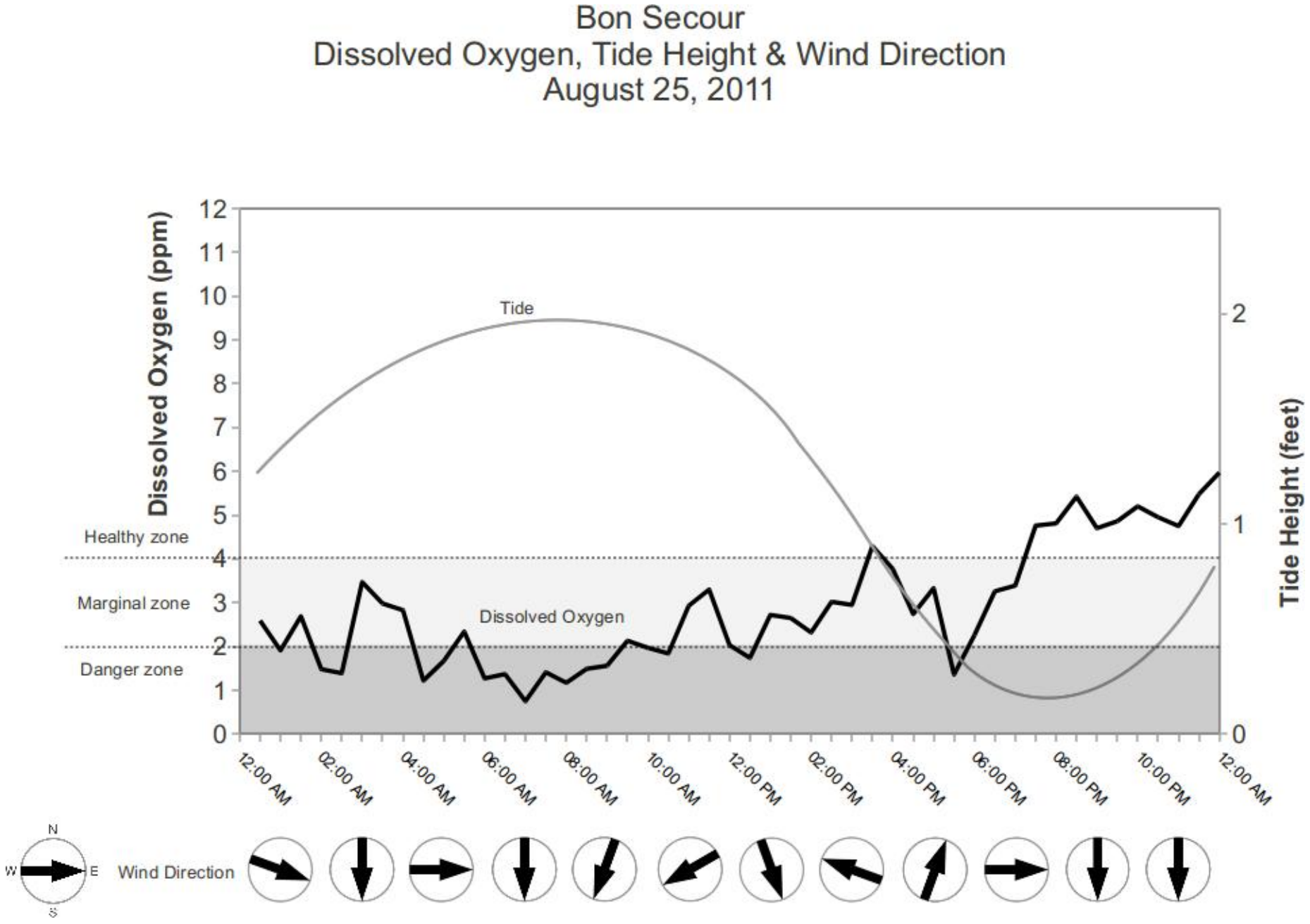
5. Share your conclusions with the class. Were all conditions for a jubilee event present on June 25, August 5, or August 25, 2011? Provide evidence to support your findings. Do you think researchers could predict a jubilee before it happened? Why or why not?

Data Log

Date	What was the time range of the lowest dissolved oxygen levels on this day?	Was the dissolved oxygen (DO) level near or below 2 ppm on this day?	Was the tide rising (water entering the bay) or falling (water leaving the bay) near dawn on this day?	Was the wind easterly (blowing from the east) near dawn on this day?
June 25, 2011				
August 5, 2011				
August 25, 2011				


Bon Secour
Dissolved Oxygen, Tide Height & Wind Direction
June 25, 2011
Dissolved Oxygen (ppm)
Tide Height (feet)
Dissolved Oxygen
Tide
Healthy zone
Marginal zone
Danger zone
12:00 AM
02:00 AM
04:00 AM
06:00 AM
08:00 AM
10:00 AM
12:00 PM
02:00 PM
04:00 PM
06:00 PM
08:00 PM
10:00 PM
12:00 AM
N
W
E
S
Wind Direction


Bon Secour
Dissolved Oxygen, Tide Height & Wind Direction
August 5, 2011
Dissolved Oxygen (ppm)
Tide Height (feet)
Tide
Dissolved Oxygen
Healthy zone
Marginal zone
Danger zone
12:00 AM
02:00 AM
04:00 AM
06:00 AM
08:00 AM
10:00 AM
12:00 PM
02:00 PM
04:00 PM
06:00 PM
08:00 PM
10:00 PM
12:00 AM
N
W
E
S
Wind Direction


Bon Secour
Dissolved Oxygen, Tide Height & Wind Direction
August 25, 2011
Dissolved Oxygen (ppm)
Tide Height (feet)
Tide
Dissolved Oxygen
Healthy zone
Marginal zone
Danger zone
12:00 AM
02:00 AM
04:00 AM
06:00 AM
08:00 AM
10:00 AM
12:00 PM
02:00 PM
04:00 PM
06:00 PM
08:00 PM
10:00 PM
12:00 AM
N
W
E
S
Wind Direction