ACTIVITY 3

Water Going Up, Water Going Down

Estuary Principle

Estuaries are dynamic ecosystems with tremendous variability within and between them in physical, chemical, and biological components.

Research Question

How do tides, wind, geographic processes, and site topography directly affect the nation's estuaries?

Introduction

Tides and tide-like water level changes can greatly affect the nation's estuaries. Water normally moves into and out of estuaries through the estuary's "mouths," or areas that open out into the ocean or lake. High water levels keep the estuary mouths very open and wide, whereas low water levels may cause the mouths to become closed due to sediment and sand movements. Mouth closures prevent the exchange of water between the estuary and the ocean or lake. This can mean death from estuary plant and animal species if dissolved oxygen levels are affected. In this activity, students will examine the effects of tides on estuaries, and look at real data to understand the effect on dissolved oxygen levels before and after a mouth closure.

Climate Extension

Using NOAA's Sea Levels Online map illustrating local and regional trends in sea level, students will explore variation in sea level trends across the National Estuarine Research Reserves.

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.

Permission is hereby granted for the reproduction, without alteration, of the activities contained in the Estuaries 101 Curriculum on the condition that proper attribution is given to the National Oceanic and Atmospheric Administration and the National Estuarine Research Reserve System (NERRS) as the source, and cite the following URL: http://www.estuaries.noaa.gov.

TEACHER GUIDE

Water Going Up, Water Going Down

Research Question

How do tides, wind, geographic processes, and site topography directly affect the nation's estuaries?

Content Objectives

Students will understand that:

- Both lunar tides and wind-driven seiches affect water levels in estuaries.
- Movement of sediment at the mouth of an estuary will either open or close the estuary's access to its lake or ocean.
- Tides vary throughout the day from location to location.
- Lack of tidal flushing can cause water conditions, such as dissolved oxygen, in a lagoon to deteriorate. This can harm aquatic life inside the estuary.
- If an estuary mouth is unable to open naturally, it is sometimes necessary to open the mouth artificially by dredging.
- There is a distinction between global sea level trends and local sea level trends.
- Sea levels provide an important key to understanding the impact of climate change on estuaries.

Exercises

Exercise 1: What Do Tides Have To Do With It?

In this exercise, students will make a "human size" graph of tides on a classroom wall to understand variability of tides at different locations. Students will investigate different estuary reserves in the NERR system to examine how tides vary throughout the day and from location to location.

Climate Extension

Using NOAA's Sea Levels Online map illustrating regional trends in sea level, students will compare sea level trend data from tide stations near National Estuarine Research Reserves. Students will discuss why there are regional differences in sea level trends across the National Estuarine Research Reserves and the impacts of these sea level trends on estuaries.

Exercise 2: (Don't) Shut Your Mouth

Students will compare and contrast the estuary mouth closures taking place at Los Peñasquitos Lagoon in California and Old Woman Creek in Ohio. Students will examine the effect of tidal and wind-driven flushing of estuary waters related to dissolved oxygen levels.

Exercise 3: Shifting Sands

Students will make a model beach in a pan using playground sand and rulers. Students will use the model beach to investigate how human-made structures affect sand movement along shorelines. Class discussion then connects the lessons about sand movement with their possible impact on estuary mouth closures.

Assessment Questions

Assessment questions based on content covered in *Water Going Up, Water Going Down* can be downloaded from the web page for this activity in the Middle School Curriculum section of the Estuary Education website at estuaries.noaa.gov.

Vocabulary

Barrier beach – spits of sand that form parallel to the shore.

Data logger – instrument that measures water quality parameters in such places as estuaries.

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.

Global sea level – average height of all the Earth's oceans.

Global sea level rise – increase in average height of Earth's oceans over time, which is primarily attributed to changes in ocean volume due to two factors: melting of land-based ice and thermal expansion of saltwater molecules.

Hypoxic – very low oxygen levels.

Lagoon – a small body of water separated from a larger body of water by narrow land or reefs.

Local sea level – the height of the water as measured along the coast relative to a specific point on land.

Photosynthesis – process of using energy in sunlight to convert water and carbon dioxide into carbohydrates and oxygen.

Relative sea level trends – changes in local sea level over time.

Salinity – the concentration of salts dissolved in salt water.

Sediment – particles deposited by wind or water.

Seiche – standing wave of an enclosed body of water that continues to move after the force that started it.

Tidal flushing – or the ongoing input of ocean water from tides.

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

EXERCISE 1

What Do Tides Have To Do With It?

Estuary Concept

Tides help make estuaries dynamic and variable. The effect of tides on estuaries is influenced by the estuary's location, local geology, morphology, and weather.

Focus Questions

- What is a tide?
- What is a seiche?
- How do tides and seiches affect water levels in estuaries?
- How do long term changes in sea level affect estuaries?

Performance Tasks

Students will:

- Make a wall-sized bar graph of tide heights versus student heights to understand the range of daily tide cycles around the nation.
- Define and discuss how tides are generated by the sun, the moon, and the wind.

Teacher Background

Tides are caused by the gravitational attraction of the moon and sun on water in the ocean and in very large lakes. Tides affect the height of water along the coast and, because estuaries are open to the ocean, the height of water within the estuaries. In estuaries located along ocean coasts, lunar tides are the driving force behind changing water depths in the estuary.

In many Reserves, tides are semi-diurnal. Semi-diurnal means that there are two high tides and two low tides in a 24 hour period. The relative positions of the moon and sun in relation to Earth cause variations in the heights of consecutive high and low tides throughout the month. During the new moon and full moon, we experience the greatest tidal amplitude (i.e., highest high and lowest low tide). These conditions occur when Earth, the moon, and the sun are more or less in line. These are the "spring" tides, although "spring" tides occur every month of the year and not just in the spring. Twice each month the moon is at a right angle to the Earth-sun axis. At these times, we experience neap tides or the tides with the least amplitude. Every month we have two spring tide and two neap tide periods.

In some Reserves, there is only one high and one low tide per day. This is called a diurnal tide. And, in other Reserves, a mixed tide pattern occurs (possibly two high tides and one low tide per day, or two low tides and one high tide). Storm events can also play an important role in changing water levels of both oceans and large lakes.

Overview

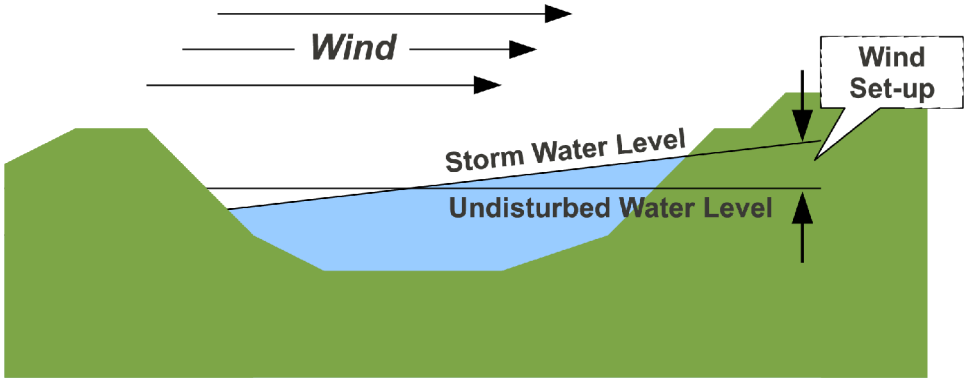
In this exercise, students will explore tides and tide-like water level changes called seiches. Students will review the causes of tides and the difference between semi-diurnal and diurnal tides. Students will also learn how winds cause the wind-driven seiches in the Great Lakes. Most importantly, students will learn how tides and seiches can affect estuaries.

Time Required

One 45-minute class session

Estuaries bordering the Great Lakes also experience tides, but these tides are very small. For example, in the Lake Superior NERR and Old Woman Creek NERR, the lunar tide effect is only about 4 cm each day. For this reason, there is no need for Great Lakes tide charts.

However, wind can also influence the height of the water in large bodies of water, such as the Great Lakes. A meteorological effect due to air pressure and winds creates a phenomenon called a "seiche" (SAYSH). The seiche starts when the wind essentially pushes down on one end of the lake which, in turn, causes the water in the other end of the lake to slosh upwards.



The water piled on the far end then sloshes back toward the end where the water had been pushed down. This sets up a sloshing back and forth of water within the lake. This is the actual seiche. The water will keep reverberating back and forth across the lake until equilibrium is achieved.

How big are seiches? During large storms, the difference between high and low water levels in Lake Erie caused by winds can be greater than 16 feet at each end of the lake! This is comparable to ocean tides at some reserves. The effect of such storms on estuaries at the farthest ends of the lake will result in large water level change in those estuaries. The effect of such storms on centrally positioned estuaries, such as Old Woman Creek NERR on Lake Erie's south shore, is much less (changing perhaps two to four feet) during the seiche.

Seiches along the Great Lakes allow estuary mouths flushing as fresh lake water surges into and out of the estuaries. This is similar to how tides influence flush water in and out of saltwater estuaries along the ocean coasts. Take Old Woman Creek estuary for example, when the wind blows across Lake Erie from the north, water is pushed into the estuary on the lake's south shore. Monitoring equipment in the estuary detects an increase in water level and water clarity and a decrease in the water's mineral content. When the water sloshes back out of the estuary, the equipment shows reduced water levels and increases in both water cloudiness and mineral content.

Climate Extension

Tides, seiches, and specific flood events all represent short-term variations in water levels in estuaries over the course of a day, while long term variations can track changes in water level over several years. Understanding long term trends in sea level, as well as the relationship between global and local sea level, provides critical information about the impacts of the Earth's climate on our oceans. Global sea level rise is primarily attributed to changes in ocean volume

due to two factors: melting of land-based ice and thermal expansion of saltwater molecules. Melting of glaciers and continental ice masses, which are linked to changes in air temperature, can contribute significant amounts of freshwater input to the Earth's oceans. Additionally, a steady increase in global air temperature creates an expansion of salt water molecules, thereby increasing ocean volume. Local sea levels in estuaries are impacted by global sea level trends as well as regional factors such as ocean circulation, wind and atmospheric pressure, tectonic subsiding or rebounding, and human activities like oil extraction or building of levees.

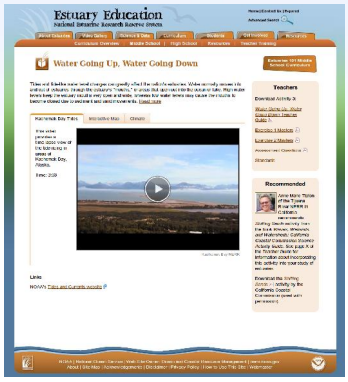
As the sea rises, the wetlands and marshes of estuaries will erode, and new wetlands will form inland as previously dry areas are flooded by the higher water levels. The amount of newly created wetlands and marshes will most likely be much smaller than the lost area of wetlands - especially in developed areas protected with bulkheads and other structures that keep new wetlands and marshes from shifting inland. The “drowning” of marshes represents a significant loss of important estuarine habitat.

For more information about sea level change please conslt the frequently asked questions page on NOAA's Tides and Currents website.

Teacher Preparation

1. Visit the web page for this activity in the Middle School Curriculum section of the Estuary Education website, and watch the Kachemak Bay, AK time-lapse tidal action video. Showing this video to your students will help them understand how tides change the water depth along the ocean coast and therefore changes water depth within estuary entrances.
2. Information about tides at many different locations around the country can be found via the site http://tidesandcurrents.noaa.gov/. This site is useful for showing your students how different locations have different tides (e.g., diurnal, semi-diurnal, mixed, etc.). Click on the map in the middle of the screen. Blue pins help you zoom in on specific states. The pink pins represent tide recording sites. Click on a pink pin to open a popup window with information on today’s tides at that location.
3. Students may be particularly interested in looking at water depth graphs that show the daily tide cycle. You can find these graphs by selecting “Tide Prediction” on the popup for each tide recording site.
4. You may choose to do this exercise in metric units. However, just as your students will be more likely to know their heights in feet and inches, tides along the coastal United States are most often reported in feet and inches. The above NOAA tide information site defaults to reporting tides in feet.
5. Make copies of Student Master: *What Do Tides Have to Do With It?*
6. Choose ahead of time which NERRs to assign to your students. Because students will need to use computers to access the online tidal information, the more Reserves that they investigate, the longer the activity may take. Consider having teams of students and limiting the number of Reserves. One suggestion might be to assign 3 Pacific coast Reserves, 3 from the Atlantic coast, and then 1 each from the Gulf coast and the Great Lakes.
7. Going from the sticky notes on the classroom wall to creating the bar chart

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.



may be easier if you can use different color sticky notes for student heights, low tides, and high tides.

Procedures

1. Show your students the time-lapse video of the tides in the Kachemak Bay, Alaska NERR, found on the web page for this activity in the Middle School Curriculum section of the Estuary Education website.
2. Tell students that there are two basic ways water enters the mouths of estuaries: 1) tidal action from the ocean; and 2) strong winds from a freshwater lake. Use a projector and/or computer to show your students the diagrams on Teacher Master: *Water Height Caused by Tides and Winds.* Share information from the Teacher Background to give your students more information on how water enters the mouths of estuaries. (Note: The rest of this exercise is primarily about tides, not seiches. You may choose to review the tide diagram at this time and come back to discuss the wind-driven water changes diagram with your students at the end of the exercise.)
3. Have students help each other measure their own heights in feet and inches. Each student should record their height on their copy of the Student Master: *What Do Tides Have To Do With It?* Students should then convert their heights to decimal feet (5 feet 6 inches becomes 5.5 feet). Each student should also write his or her own name and height in decimal feet on a separate sticky note.
4. Assign each student or team of students a NERR site to investigate. Students may need to consult the interactive estuary map in the Middle School Curriculum section of the Estuary Education website to find their Reserve's location before finding a nearby tide station on the NOAA's Tides and Currents website: http://tidesandcurrents.noaa.gov/.
5. Have each student or team of students take turns and stick their low tide sticky notes on the classroom wall. Sea level is the floor, so that is zero feet height. Try to get the heights approximately correct. When students are done with their low tide sticky notes, have them place their high tide sticky notes on the wall as well. You may need to carefully stand on a chair for a few of these!
6. Now have students stick the sticky notes with their heights onto the wall as well. Remind students that, if sea level is the floor, then their heights are measured relative to sea level, just like the heights of the tides.
7. Once all the sticky notes have been placed on the wall, try to group similar sticky notes. Group similar (the same half foot height) tide height notes together. Group similar student height notes together. Put similar height notes side-by-side. This will help students count the notes and create their bar charts. Ask the students if there is ever a time when the water would be over the heads of everyone in the class.
8. When students have completed their bar chart and answered the questions on the Student Master, review their answers in class. Possible answers are provided below.

Take Note

This activity includes a Climate Extension. Please make sure to review the procedures and materials related to the Climate Extension before proceeding with this activity.

Materials

- Teacher Master: *Water Height Caused by Tides and Winds*

Per class

- Computers with Internet access
- Sticky notes (such as Post It brand notepads)

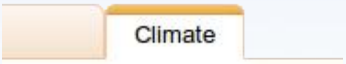
Per student

- Pencil or marker
- Student Master: *What Do Tides Have To Do With It?*

Climate Extension

9. To introduce the concept of global sea level rise play NASA's short video Shrinking Ice, Rising Seas.
10. Discuss the movie with the students. What are two major factors that contribute to global sea level rise? How many meters do some scientists think the global sea level could rise over the next 100 years? (Please note: Other scientists with the Intergovernmental Panel on Climate Change expect a range in sea level rise to be 18 – 59 cm by 2100.) Why is it challenging to predict sea level change? What would be the impacts to coastal areas and estuaries?
11. Next, have the students explore regional sea level trends for the same Reserves and tide stations they were assigned to for the first part of this exercise using the Sea Level Trends pages on NOAA's Tides and Currents website. Have students complete tasks and questions outlined on the *Climate Extension* student master.

For resources and links related to this Climate Extension, look for the Climate tab on the web page for this activity in the Middle School Curriculum section of the Estuary Education website: http://estuaries.noaa.gov.



Questions and Possible Answers

1. **Compare your height to the height of the tide at your assigned Reserve during the day. Is there ever a time when the water would be over your head?**

   Student answers will vary depending on their heights and the heights of tides at their assigned Reserve location.

2. **Look at your bar chart. Are the heights of most of the high tides greater than the heights of most of your classmates?**

   Generally, the tidal range along most U.S. coastal locations is around 3 to 6 feet. The heights of your students are likely to be just above the highest tide heights for most, but not all, of the Reserve locations.

3. **What is a tide?**

   A tide is the regular variation in the surface level of water in the ocean, in bays, gulfs, and estuaries, caused by the gravitational attraction of the moon and sun on Earth and Earth's large bodies of water.

4. **What causes tides?**

   Tides are caused by the gravitational pull of the moon on Earth and Earth's oceans and, to a lesser extent, the pull of the sun. "Tides" observed on lakes are seiches, which are atmospheric pressure or wind-driven changes in water level.

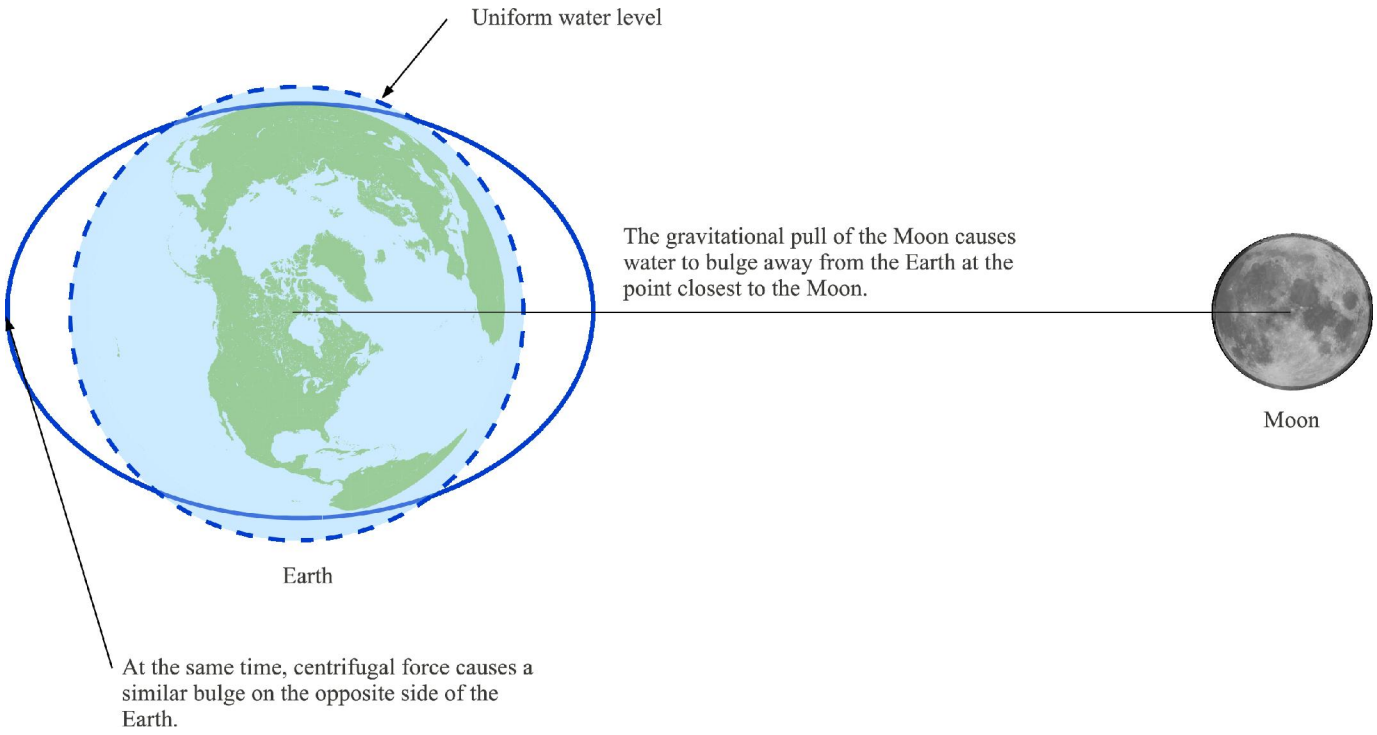
5. **Reserve scientists monitor water levels daily at most sites. Why is this important?**

   Understanding patterns of change in today's estuary can help scientists understand and predict future water level changes and their impacts.

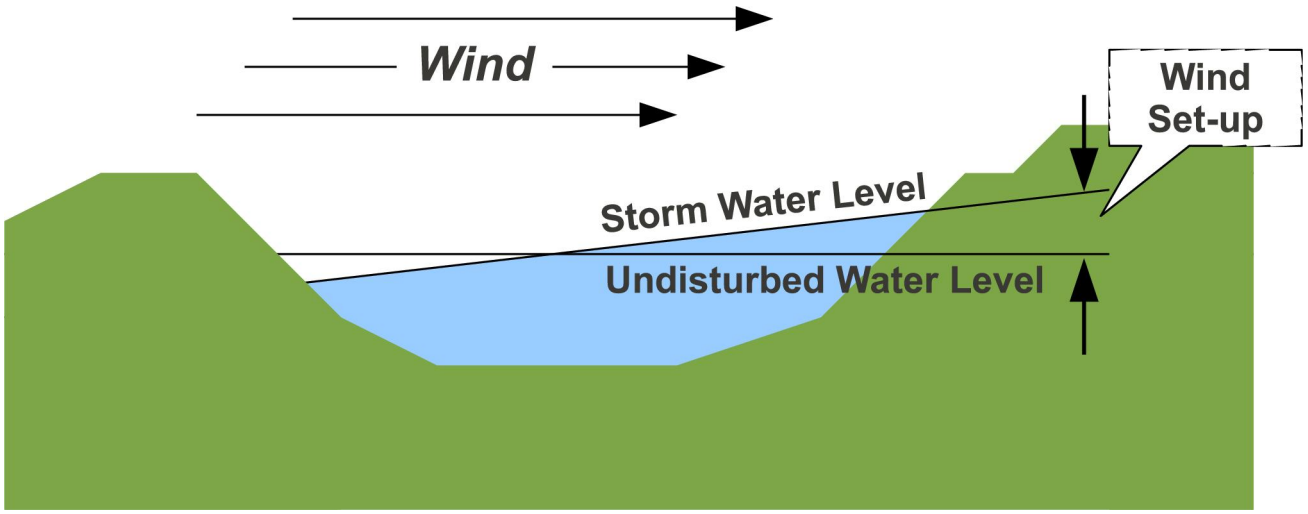
TEACHER MASTER

What Do Tides Have To Do With It?

Water Height Due to Lunar Tides



Water Height Caused by Winds



STUDENT MASTER

What Do Tides Have To Do With It?

For estuaries with mouths opening into the ocean, water level within the estuaries is highly dependent on tides. Fresh water enters the estuary from the upstream watershed. But water also enters and exits the estuary every day because of the tides. The movement of this water in and out of the estuary affects the water in the estuary. It also affects the physical or geographic features of the estuary mouths. High water keeps the mouths open and wide, whereas low water levels may cause the mouths to shut due to sediment and sand movements.

Procedures

1. Use a yard stick to measure your height. Record your height below in feet and inches.

   _____

   Now convert your height in feet and inches to a height in decimal feet. (Hint: Convert the inches to feet by dividing the number of inches by 12.)

   _____

   Write your name and height on a sticky note.

2. What is the name of the Reserve that your teacher has asked you to investigate?

   _____

   You may want to consult the interactive map on the Estuary Education website to find the location of this Reserve.

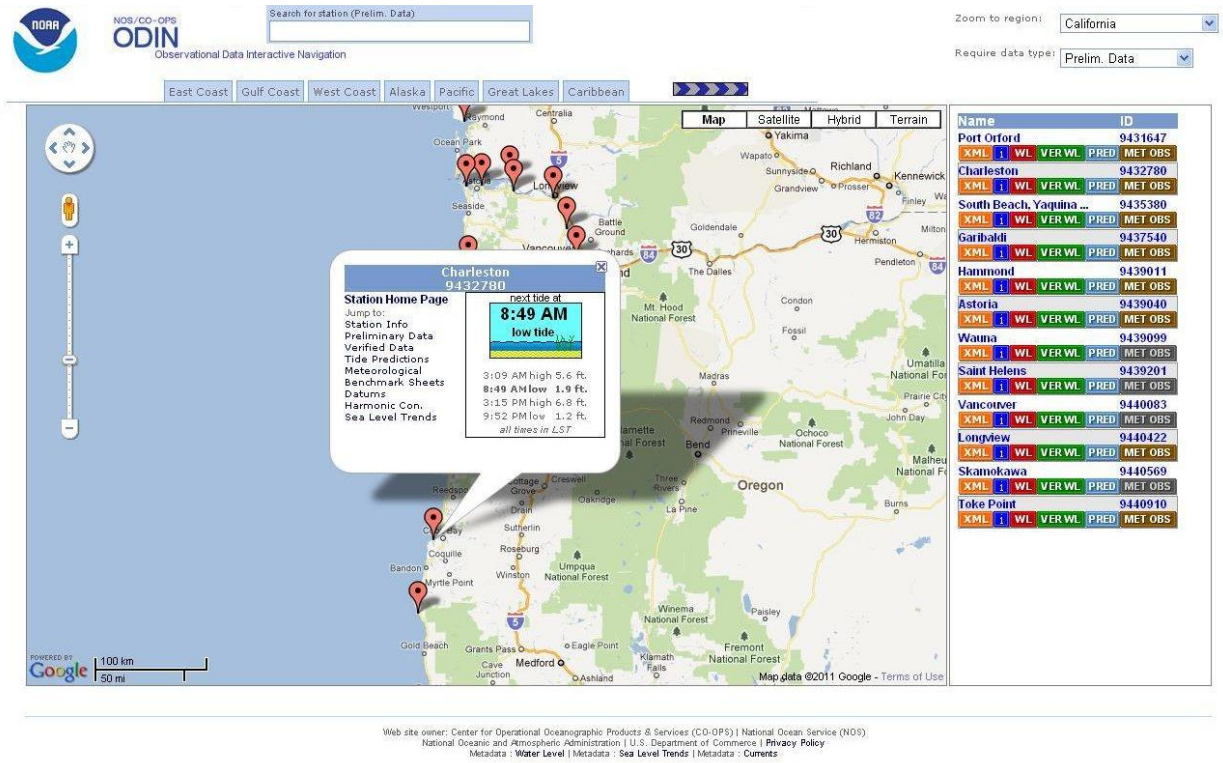
3. Next you will want to get on a computer and find tide information for a location near your assigned Reserve. Go to NOAA's Tides and Currents website:

   http://tidesandcurrents.noaa.gov/

   Click on the map in the middle of the screen. Blue pins on the map on the next page can help you zoom in on specific states or you can use the map's zoom controls. The pink pins on the map represent tide recording sites. Find a pink pin closest to the location of your assigned Reserve.

   What is the name of the NOS tide station nearest your assigned Reserve?

   _____



4. Click on the pink pin to open a popup window with information on today's tides at that location. What you see should look similar to the above screen that shows a data popup for Charleston, Oregon, a tide data site very near Oregon's South Slough Reserve.

   Look in the popup for information on today's tides at that location. Identify the height of the highest tide and the height of the lowest tide for that site. Most sites along the Pacific and Atlantic coasts have semi-diurnal tides. They have two high tides and two low tides each day. Be sure to record both.

   Height of highest high tide _____

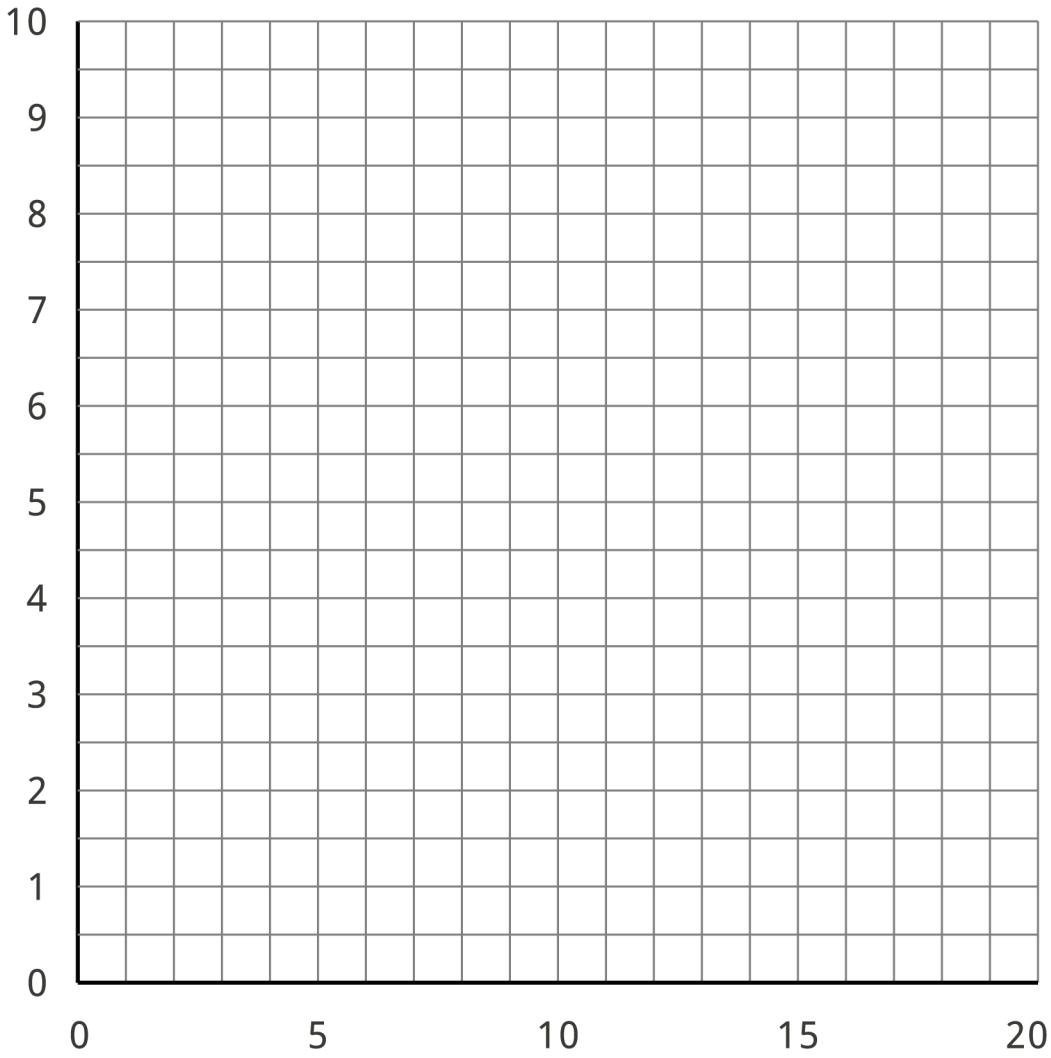
   Height of second high tide (if any) _____

   Height of lowest low tide _____

   Height of second low tide (if any) _____

5. Write the name of your Reserve and the height of each tide on separate sticky notes. Label the high tide notes "High tide" and the low tide notes "Low tide." You should have a separate sticky note for each high tide and each low tide. Your teacher will tell you what to do with the sticky notes.

6. Make a bar chart from the sticky notes on your classroom wall. The vertical axis is height in feet. This is the height of students in your class and the height of the tides at all of the Reserves your class examined. The horizontal axis is a count of the number of tides at a particular height or number of students with a particular height. Group sticky notes into half feet. Your bars will run horizontally. Each half foot should have a bar for tides and another bar for students. Use color pencils to color in the bars and use the key at the top of the chart to indicate which color indicates tides and which color indicates students.



Questions

1. Compare your height to the height of the tide at your assigned Reserve during the day. Is there ever a time when the water would be over your head?

2. Look at your bar chart. Are the heights of most of the high tides greater than the heights of most of your classmates?

3. What is a tide?

4. What causes tides?

5. Reserve scientists monitor water levels daily at most sites. Why is this important?

CLIMATE EXTENSION

Sea Level Trends

Procedures

To complete the questions below visit the Sea Level Trends pages on NOAA's Tides and Currents website:

http://tidesandcurrents.noaa.gov/sltrends/sltrends.shtml

On the Sea Levels Online page use the map's zoom controls to find the sea level station nearest your assigned Reserve. Note that not every tide station has sea level trend data so you may have to use the next nearest tide station to your assigned Reserve.

What is the name of the NOS tide station nearest your assigned Reserve? _____

1. Click on the tide station to read the popup for information on sea level trends at that location and record the following information:

   Is the sea level rising or falling? _____ What is the mean sea level trend in mm/yr? _____

   At this rate, how many cm of change would this calculate for the next 100 years? _____

   How many feet of change would this calculate for the next 100 years? _____

2. Repeat these steps at a NOS tide station on a different US coast from your assigned reserve. Read the popup for information on sea level trends at that location and record the following information:

   What is the name of the NOS tide station? _____

   Is the sea level rising or falling? _____ What is the mean sea level trend in mm/year? _____

   At this rate, how many cm of change would this calculate for the next 100 years? _____

   How many feet of change would this calculate for the next 100 years? _____

3. New methods of measuring elevation by satellite indicate a global sea level rise rate of 3 mm/year. How does this global sea level rise trend compare to the trends from the NOS tide station recorded above?

4. Why do you think there are differences in the regional sea level rates and global sea level rates?

EXERCISE 2

(Don't) Shut Your Mouth

Estuary Concept

Estuaries can change quickly. They are constantly affected by the fresh water entering the estuary from upstream as well as by tides, winds, and water currents that can bring in water from either lakes or oceans.

Focus Questions

- How do mouth closures affect water depth in estuaries?
- How do mouth closures affect water quality parameters, such as dissolved oxygen, in estuaries?

Performance Tasks

Students will:

- Compare and contrast the mouth closures at Los Peñasquitos Lagoon, CA and Old Woman Creek Estuary, OH.
- Examine graphs from Los Peñasquitos Lagoon, CA and Old Woman Creek Estuary, OH to compare the mouth closure effects on water depths and dissolved oxygen levels.

Teacher Background

Water quality data loggers located in estuaries record such parameters as water temperature, salinity (or, in fresh water, "conductivity" since there is little dissolved salt to measure), water depth, and dissolved oxygen.

OWC NERR, Old Woman Creek Estuary, and Tijuana River NERR, Los Peñasquitos Lagoon, are the only two estuaries in the NERR system where the estuary mouths routinely close. The effects of this closure may be quite different.

Los Peñasquitos Lagoon: Closure of a Saltwater Estuary

When mouth closures occur in saltwater estuaries, data loggers normally record decreasing levels of dissolved oxygen in the estuary water. These decreasing levels are caused by the respiration of aquatic organisms. When the rate at which the organisms use up oxygen outpaces the rate at which phytoplankton and other green aquatic plants produce oxygen, the levels of dissolved oxygen in the water go down.

Water that has dissolved oxygen levels of less than 2 ppm (or 2 mg/L) is said to be hypoxic. At that level of dissolved oxygen, aquatic life is in danger of dying. In order to prevent the die-off of estuary organisms, it is sometimes necessary to mechanically open (e.g., dredge) the estuary mouths and let water flow into and out of the lagoons. Since dredging operations are expensive and disruptive, it is important to carefully analyze and evaluate water quality data to determine whether and when these operations are necessary.

The Tijuana River NERR is located in a part of the country that has a short, wet

Overview

In this exercise, students will study and analyze estuary mouth closures at two different sites in two different parts of the country: Los Peñasquitos Lagoon, CA (in the Tijuana River NERR) and Old Woman Creek Estuary, OH (OWC NERR). By comparing the mouth closures at these two different sites, students learn how mouth closures affect aquatic life in the estuaries. Specifically, students will see how mouth closures affect specific measurements of water quality, such as dissolved oxygen, within the estuaries. In addition, students will learn how climate and geography at the two different sites influence the effects of mouth closures on the estuaries.

Time Required

One or two 45-minute class sessions

winter and a long, dry summer. The area receives only 10 inches of annual rainfall. In these dry conditions, it can become necessary to mechanically open the estuary mouth since there are no natural heavy rain events that can break through the barrier bars and open the estuary mouth during the summers.

Old Woman Creek: Closure of a Freshwater Estuary

Freshwater estuary mouth closures are not the same as saltwater estuary mouth closures. When the mouth of a freshwater estuary closes, there may or may not be a significant drop in dissolved oxygen reported by the data loggers. For example, when the mouth of Old Woman Creek estuary is closed, phytoplankton populations in the lagoon build up and their photosynthesis can drive dissolved oxygen levels up during sunlight hours. However, at night, respiration from all of the living aquatic organisms can drive the dissolved oxygen levels back down, sometimes to hypoxic conditions (less than 2 mg/L or 2 ppm).

Mouth closures in freshwater estuaries can occur year round dependent on a variety of seasonal variations in water inputs and or wind events on Lake Erie. OWC NERR receives far more annual rainfall than the Tijuana River NERR, with a significant wet season in the winter and spring. These rains and melting snow in the OWC watershed may cause water levels in the estuary to rise and eventually break through any barrier beach closing the estuary's mouth. Significant rainfall events during the summer and fall can also open the estuary mouth.

Teacher Preparation

1. Read the Teacher Background above to review the importance of phytoplankton, dissolved oxygen, and water flow in estuaries.
2. Look at the graphs found on the Student Master: *(Don't) Shut Your Mouth.* You will need to help your students read these graphs that have two, dissimilar vertical axes and scales.
3. Make copies of Student Master: *(Don't) Shut Your Mouth.*

Procedures

1. Divide your class into teams of two students per team.
2. Distribute copies of Student Master: *(Don't) Shut Your Mouth.*
3. Have your students look at the Student Master. Review with your students how to read the two Dissolved Oxygen and Water Depth graphs on the Student Master. As each graph is actually displaying two separate sets of data, students need to be able to tell which data line goes with which vertical axis and scale.
4. Once students have completed work on the Student Master, discuss their answers to the questions in class. Possible answers are provided below.

Materials

Per student:

- Student Master: *(Don't) Shut Your Mouth.*

Questions and Possible Answers

1. **In San Diego County, there are normally two high tides and two low tides each day. Look at the graph. On what day did the mouth closure at Los Peñasquitos Lagoon make it "appear" that there was only one high tide and one low tide?**

There appears to only be one high tide and one low tide on January 8.

2. **Hypoxia is when there isn't enough oxygen in the water for aquatic creatures to live. On which day did the water in Los Peñasquitos Lagoon become hypoxic (less than 2 mg/L)? How long did the water remain hypoxic?**

   Water in the lagoon became hypoxic starting on January 16 and remained hypoxic through the end of the displayed dates (i.e., at least through January 21).

3. **Why do you think the spike in water level occur at the same time as the spikes in dissolved oxygen?**

   The spikes in water level represent high tides. At high tide, water from the ocean enters the estuary through the mouth and water levels in the estuary rise. Water from the ocean is full of dissolved oxygen. The tidal movement of the water from the ocean into the estuary brings oxygen-rich water into the estuary, which we see as spikes in dissolved oxygen levels.

4. **When did the mouth close at Old Woman Creek? How do you know?**

   The mouth closed on September 15, 2008. Water levels rose suddenly on that day and stayed high.

5. **Hypoxia is when there isn't enough dissolved oxygen in the water for aquatic creatures to live. What day did the water get hypoxic (less than 2 mg/L)?**

   The water became hypoxic on September 20, 2008.

6. **After the mouth closed in Old Woman Slough, there was an abrupt drop in dissolved oxygen. Then the levels of dissolved oxygen began to rise again. What biological process may explain this recovery in DO levels?**

   Since the mouth is closed, phytoplankton inside the estuary are not flushed out into the lake. The phytoplankton populations increase. Photosynthesis by the phytoplankton increases the dissolved oxygen levels.

7. **Before the mouth closed in Old Woman Slough, dissolved oxygen levels experienced a large number of highs and lows. After the mouth closed, oxygen levels show fewer numbers of these same fluctuations. Why?**

   Before the mouth closed, the water within the estuary was affected by water from Lake Erie washing in and out of the estuary through the mouth. This movement of water results in the high and low dissolved oxygen readings. After the mouth closed, water from the lake no longer entered the estuary. The remaining changes in dissolved oxygen levels in the estuary are due to day/night activity by phytoplankton within the estuary.

8. **Think about both estuaries you've looked at in this exercise. How do tides, wind, geology, and site characteristics directly impact the nation's estuaries?**

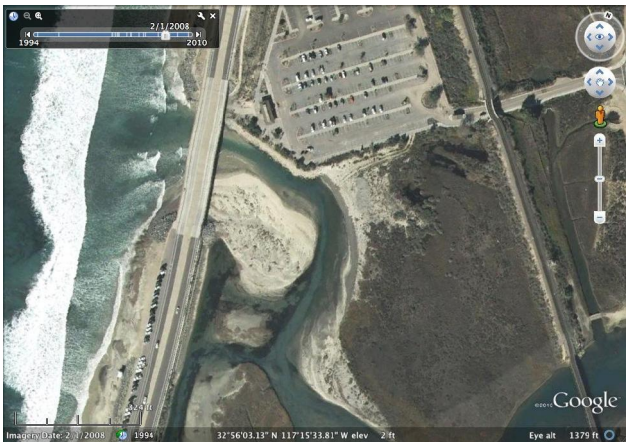
   All of the above affect the movement of water and the movement of sand near the mouths of estuaries. These movements determine whether the mouths of the estuaries are open or closed. Whether the estuary mouths are open or closed affects the amount of dissolved oxygen available to aquatic organisms in the estuary.

STUDENT MASTER

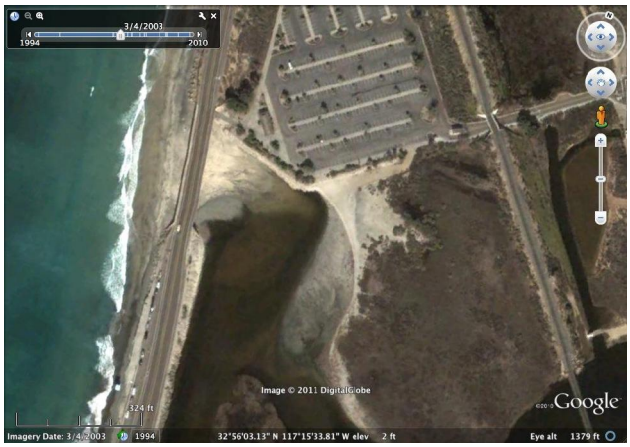
(Don't) Shut Your Mouth

Los Peñasquitos Lagoon

Los Peñasquitos Lagoon is a small estuarine ecosystem in San Diego, California. Human activity in the area of the lagoon has caused changes to the estuary system. For example, the construction of a railroad trestle causes the lagoon mouth to close more frequently than it would naturally. When these mouth closures occur, water from the ocean is less likely to reach the lagoon. With less water coming in from ocean, the overall health of the estuarine ecosystem suffers.

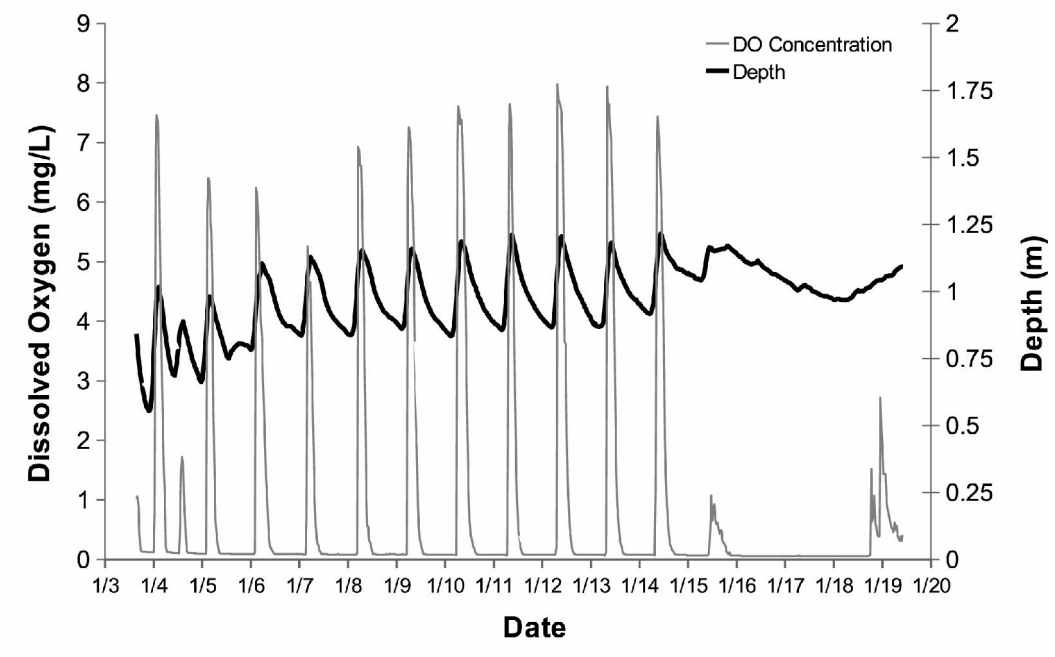


Los Peñasquitos Lagoon during open conditions.



Los Peñasquitos Lagoon during closed conditions.

Let's look at how a mouth closure affects Los Peñasquitos Lagoon. The graph below shows dissolved oxygen and water depth (samples taken every 15 minutes) during a 17-day period when a mouth closure event occurred:



Los Peñasquitos Lagoon During and Following a Mouth Closure

The estuary's mouth wasn't fully closed during the first two weeks shown on the graph. On January 5, the mouth is open. You can see two high tides and two low tides. This is the normal semi-diurnal tide characteristic of the region. However, over the next couple of days, the two high tide spikes seem to become one. The tides haven't changed. So what happened? You may notice that the overall water level in the lagoon is gradually increasing. A sill or barrier is forming at the estuary mouth. Water is piling up in the lagoon behind the sill. Now there is just one tidal exchange per day, indicating that only the higher tides make it into and out of the lagoon. During the last week, you see no tidal water exchange on the graph. The mouth of the estuary is fully closed.

Looking at dissolved oxygen, you can see a very clear relationship with the tidal exchange. When well-oxygenated ocean water flows in the lagoon at high tide, oxygen shoots up. When tides begin to ebb, anoxic (low oxygen) water from the lagoon and watershed moves past the data logger. As the mouth becomes increasingly blocked, the tidal water exchange decreases and finally ceases. The water becomes hypoxic, increasing the possibility of events such as large-scale fish kills.

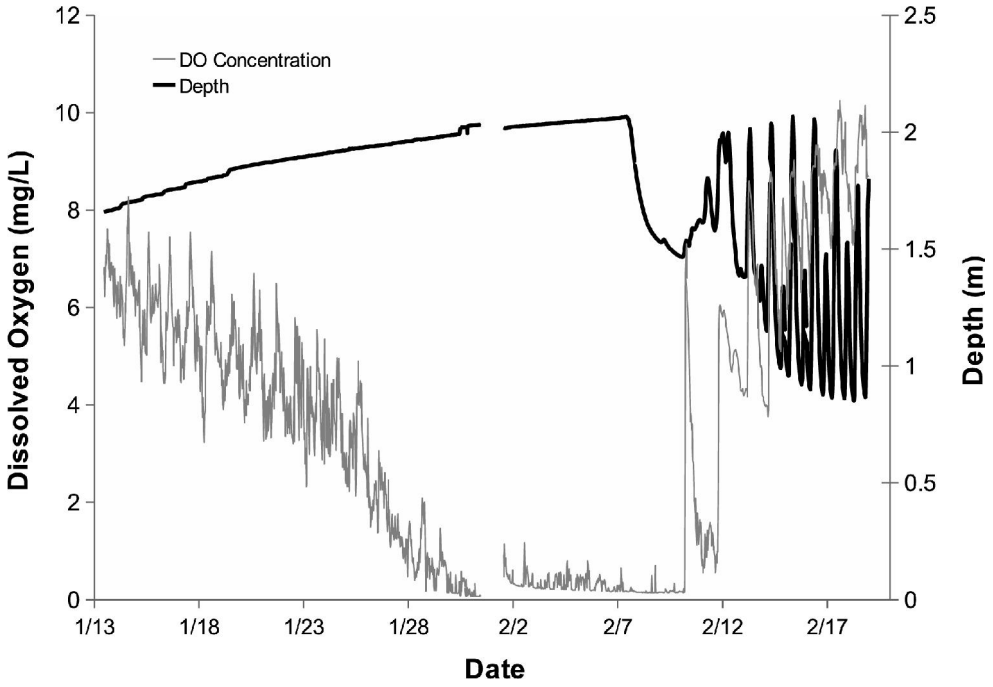
Examine the graph on the previous page for Los Peñasquitos Lagoon to answer the following questions:

1. In San Diego County, there are normally two high tides and two low tides each day. Look at the graph. On what day did the mouth closure at Los Peñasquitos Lagoon make it "appear" that there was only one high tide and one low tide?

2. Hypoxia is when there isn't enough oxygen in the water for aquatic creatures to live. On which day did the water in Los Peñasquitos Lagoon become hypoxic (less than 2 mg/L)? How long did the water remain hypoxic?

3. Why do you think the spike in water level occur at the same time as the spikes in dissolved oxygen?

What happens to the estuary if the mouth doesn't get reopened? The graph below shows dissolved oxygen levels and water depth at Los Peñasquitos Lagoon during a mouth closure event:



Los Peñasquitos Lagoon During a Mouth Closure and After Opening

During the mouth closure, water from the watershed piled up in the lagoon behind the barrier that formed at the estuary mouth. The water level slowly, steadily rose. At the same time, the dissolved oxygen levels decreased and eventually stayed near zero. Clearly, aquatic life within the estuary was suffering at this point. On February 8, workers dredged open the estuary mouth, allowing the hypoxic water within the estuary to flow out and restoring natural flow of ocean water into the estuary via the tides. Dissolved oxygen levels quickly recovered.

Old Woman Creek

Now let's look at a different estuary that experiences mouth closures. Compare these pictures of Old Woman Creek estuary when the estuary mouth is open and when it is closed.

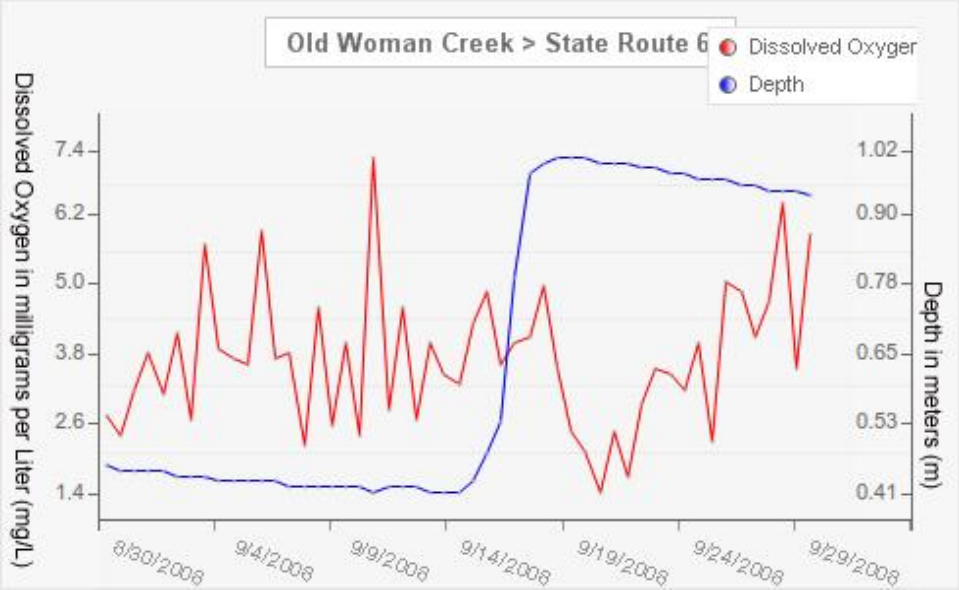
Old Woman Creek estuary after runoff from a heavy rain has cut through the barrier beach, leaving estuary mouth open to Lake Erie.

Old Woman Creek estuary when the mouth has been closed off from Lake Erie by a barrier beach.

Water levels in the Old Woman Creek estuary rise and fall dependent on whether or not the estuary mouth is closed. When the barrier beach closes the mouth of the Old Woman Creek estuary, the barrier beach blocks the flow of water from the lake into the estuary, as well as the flow of water from the estuary out into the lake. The estuary mouth will remain closed until waters from significant rains upstream in the Old Woman Creek watershed create enough water pressure to break through the barrier beach and reopen the mouth. This natural process can occur at any of the Great Lakes estuaries.

At Old Woman Creek, mouth openings and closures occur frequently throughout the year. The barrier beach that closes the estuary mouth at Old Woman Creek is formed from sand moved by currents and wind-driven waves. The wind blowing across Lake Erie sets up the phenomenon called a seiche (pronounced SAYSH). In a seiche, wind-driven water gets pushed down on one end of the lake, piles up on the other end of the lake, and then sloshes back and forth from end to end until water levels return to equilibrium.

When the Old Woman Creek estuary mouth is closed, phytoplankton tend to build up within the estuary. The phytoplankton rapidly produce large amounts of oxygen in the water. In a typical freshwater estuary mouth closure, the dissolved oxygen levels within the estuary drop at first due to the absence of water entering the estuary form the lake. However, because of the phytoplankton, the dissolved oxygen levels usually increase over time.



Old Woman Creek, State Route 6

Examine the graph for Old Woman Creek above and answer the following questions:

4. When did the mouth close at Old Woman Creek estuary? How do you know?

5. Hypoxia is when there isn't enough dissolved oxygen in the water for aquatic creatures to live. What day did the water get hypoxic (DO less than 2 mg/L)?

6. After the mouth closed, there was an abrupt drop in dissolved oxygen. Then the levels of dissolved oxygen began to rise again. What biological process may explain this recovery in DO levels?

7. Before the mouth closed, dissolved oxygen levels experienced a large number of highs and lows. After the mouth closed, oxygen levels show fewer numbers of these same fluctuations. Why?

8. Think about both estuaries you've looked at in this exercise. How do tides, wind, geology, and site characteristics directly impact the nation's estuaries?

EXERCISE 3

Shifting Sands

Estuary Concept

Inputs of water, heavy sediment loads, and modification by human activities can change estuary mouth openings.

Focus Questions

- How does the movement of sand and sediment influence estuary mouth closings?
- How do structures that are built to protect the coast from erosion change beaches?

Performance Tasks

Students will:

- Describe the forces that naturally shape beaches.
- Understand the advantages and limitations of artificial structures built to control beach erosion and deposition.

Teacher Preparation

1. Read the complete *Shifting Sands* activity. You will find the activity as a PDF file on the web page for this activity in the Middle School Curriculum section of the Estuary Education website.
2. Review the instructions on how to build the model beach found on page 73 of the *Shifting Sands* document. You may want to try the activity yourself before assigning it to your students.
3. Assemble materials for your class as described in the *Shifting Sands* document. Playground sand is usually sold in 50 lb bags. One bag should be adequate for an average class. Dry the sand and save it for reuse. Note: Because of the potential for inhalation of silicon, playground sand often has a warning label as a potential cancer risk. If this is a concern, you might decide to have students wear masks.

Procedures

1. Divide your class into teams of four or more students per team.
2. Distribute copies of handouts and instructions to each team.
3. You may choose to discuss the handout Shifting Sands: *Groins and Jetties* with your students before they start work on their model beaches. You might also want to have the class read aloud the glossary and background material found on the handout Shifting Sands: *Background and Model Instructions*.
4. Student teams will follow the instructions on page 73 of Shifting Sands: *Background and Model Instructions* to create the model beach.

Overview

Students will find that construction of bridges and railroad trestles can affect sand movement just as much as strong waves from tides, storm surges, and water flowing from rivers. In this exercise, students will make a model beach using a pan, sand, and rulers. Students will use the model beaches to investigate how human-made structures affect sand movement. Students are then asked to consider how this sand movement may lead to estuary mouth closures.

Time Required

Two 45-minute class sessions

Materials

Please see the *Shifting Sands* lesson document (PDF) for a list of materials (page 70) for creating the model beaches.

Per team

- Copy of handout, *Shifting Sands: Groins and Jetties* (page 71)
- Copy of instructions, *Shifting Sands: Background and Model Instructions* (pages 72 and 73)

5. Once students have cleaned up, lead a class discussion about how the beach processes they observed in their models might affect estuaries. This is your opportunity to make the connection between mouth closures and the processes of beach erosion and deposition. That connection is not made within the Shifting Sands activity; you have to do that yourself.