

ACTIVITY 1

Where Rivers Meet the Sea

Estuary Principle

Estuaries are interconnected with the world Ocean and with major systems and cycles on Earth.

Research Question

What are estuaries?

Introduction

Did you know that estuaries are interconnected with the world-ocean and major systems on Earth?

Estuaries are places where the planet's major environments of land, ocean, rivers, and the atmosphere come together. Estuaries are found all-over the planet, mostly in the form of salt water marshes and mangrove swamps. Estuaries, no matter where they are located on Earth, have shared characteristics. They all have a semi-enclosed body of water that has a free connection to the open sea, and fresh water derived from land drainage. The North American shoreline is ringed with estuaries.

There are twenty-eight estuarine reserve sites in the United States that make up a system of estuaries stewarded by NOAA's National Estuarine Research Reserve System (NERRS). These reserves are located in 22 of the 35 U.S coastal states from Alaska to Puerto Rico, including the Great Lakes Basin, and protect over 1.3 million acres of coastal land and waters.

You are invited to visit these estuarine reserves and their Education Coordinators to explore and study our nation's estuaries — where the rivers meet the sea.

Climate Extension

Using NOAA maps of Sea Surface Temperature, students will consider the link between ocean temperatures, currents and global climate change as it relates to estuaries.

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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.



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TEACHER GUIDE

Where Rivers Meet the Sea

Research Question

What are estuaries?

Content Objectives

Students will understand that:

- An estuary is a body of water, partially enclosed by land, where salt water from the ocean and fresh water from the land can mix.
- Estuaries can be found in coastal areas of the ocean worldwide.
- The National Estuarine Research Reserves (NERRS) are a system of estuary sites located around the coasts the United States and Puerto Rico and the Great Lakes that set the baseline for research and monitoring in estuaries.

Exercises

Exercise 1: Just What Are Estuaries?

In this exercise, students are introduced to the Estuaries 101 Middle School program and website. Students take a short, online quiz to check their initial estuary knowledge. Students examine Mobile Bay as an example of an estuary. Finally, students practice identifying four different types of estuaries.

Exercise 2: One Ocean, Many Estuaries

In this exercise, students study a world map to examine the global distribution of estuaries. Students then examine global sea surface temperature map to learn about the effects of location on ocean water temperature and of ocean water temperature on water temperature within the connected estuaries.

Climate Extension

By interpreting NOAA's Sea Surface Temperature maps, students will create their own ocean current maps and learn how the ocean currents play an important role as a climate regulator. Students will compare Sea Surface Temperature maps and consider the impacts of rising ocean temperatures on estuaries.

Exercise 3: Explore Estuaries in the NERR System

In this exercise, students first look at the entire NERR System by visiting Reserves using an online interactive map. Students will adopt a NERR site and research when the Reserve came into the system, what bio-geographic region it is found in, and what type of estuary it is. Students present their findings to the class in the form of a travel brochure.

Assessment Questions

Assessment questions based on content covered in *Where Rivers Meet the Sea* 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

Bar-built Estuary – areas where sandbars form parallel to the shore, partly enclosing the water behind them as the sandbars become islands.

Bio-geographic region – is a geographic area with similar dominant plants, animals and prevailing climate

Coastal Plain Estuary – estuary formed when rising sea level flooded existing river valley.

Delta – A low-lying sediment deposit found at the mouth of a river.

Estuary – a semi-enclosed body of water which has a free connection to the open sea and within which seawater is measurably diluted by fresh water derived from land drainage. Some unique Great Lakes coastal wetlands are referred to as freshwater estuaries. They occur where rivers and Great Lakes water mix in shallow wetlands located near the mouth of a river.

False-color map – an image that uses colors to represent differences in measured values, rather than true appearances.

Fjords estuary – a glacial trough valley now flooded with seawater to create a steep-walled inlet.

NERRS – National Estuarine Research Reserve System

Sea Surface Temperature – the average temperatures at the uppermost layer of the ocean –only a few millimeters deep. Sea Surface Temperature, often referred to as SST, can be globally monitored through satellite remote sensing.

Tectonic Estuary – created when a large piece of Earth's crust cracks, sinks or subsides and produces a depression or basin below sea level that fills with water. This type of estuary is often caused by an earthquake.

Taking It Further

In Exercise 1, instead of using the map of Mobile Bay, Alabama provide a map of a NERRS estuary near the students' school to introduce them to estuaries.

EXERCISE 1

Just What Are Estuaries?

Estuary Concept

Estuaries form an interface linking watersheds and oceans. They receive groundwater and surface water from their entire watersheds.

Focus Question

What is an estuary?

Performance Tasks

Students will:

- Take a pretest to assess how much they already know about estuaries.
- View an estuary video to establish a working definition of estuary.
- Identify different geographic types of estuaries (coastal plain, tectonic, bar-built, and fjords).

Teacher Background

An estuary is a partially enclosed body of water where two different bodies of water meet and mix.

An estuary begins where fresh water from rivers and streams flows into coastal bays and inlets. These areas of transition between the land and sea are driven by tides, but sheltered from the full force of ocean wind and waves. Most estuaries contain brackish water, which is a mixture of fresh and salt water. Some other names for estuaries include bays, bayous, lagoons, sounds, or sloughs.

It is important to note that estuaries are not just found where fresh water from rivers and salt water from the ocean meet and mix. Estuaries can also be found where fresh water from rivers or streams mixes with chemically distinct water from a large freshwater lake. These estuaries are called freshwater estuaries. Examples of freshwater estuaries are found in the Great Lakes Basin.

Each estuary has its own specific characteristics, but all estuaries play vital roles in the environment and in our lives. The four major types of estuaries based on geographic features/origins are coastal plain, bar-built, tectonic, and fjord estuaries.

A fifth estuary type, the delta estuary, is a sub-type of the coastal plain estuary, modified with the addition of large amounts of sediments deposited at the estuary mouth.

You can find additional background information about estuaries on the web page for this activity on estuaries.noaa.gov.

Overview

In this exercise, students will be introduced to estuaries. They will define what an estuary is, where estuaries are located world-wide. Students will also identify different types of estuaries; and explore why estuaries are studied and protected by the National Estuarine Research Reserve System (NERRS).

Time Required

One 45-minute class session

Teacher Preparation

1. Welcome to Estuaries 101 Middle School curriculum! The first thing you will want to do is become familiar with the Middle School Curriculum section of the Estuary Education website at estuaries.noaa.gov. Go to the website and explore. Familiarize yourself with all the exciting components.
2. Review the quiz, *Test Your Estuarine Wisdom* on the web page for this activity on estuaries.noaa.gov. This quiz is a pre-test for the curriculum. It focuses on important estuary-related content your students will be exposed to during the different learning experiences within the Estuaries 101 Middle School program.
3. Preview the video, *What is an Estuary?* It is also found on the web page for this activity on estuaries.noaa.gov. You will want to show this video to your students after they take the above quiz. The video discusses what an estuary is, the types of estuaries, and why students should care about estuaries.
4. Preview the *Estuary Landforms and Features* presentation (Power Point) found on the web page for this activity on estuaries.noaa.gov. This slideshow showcases information about the types of estuaries students will interact with during this activity.
5. Review and make copies of Student Master: *Just What Are Estuaries?*

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. Test your students' existing knowledge about estuaries. Have your students take the online pre-test, *Test Your Estuarine Wisdom*, found on the web page for this activity on estuaries.noaa.gov. Students can take the quiz directly online in a computer lab. You may also choose to project the quiz and take it together as a class by asking questions out loud and asking for answers.
2. After they have taken the pre-test, invite your students to explore estuaries by taking them to the Middle School Curriculum section of the Estuaries Education website. Tell them this site is being used by students across the country to learn more about estuaries.
3. After your students have explored the website, ask them what they think an estuary is. Write some of their definitions on the board or on a flipchart. Now have students view the video, *What is an Estuary?* Afterward, return to the student estuary definitions to see if your students have changes or additions they would like to make to their definition. Create a class definition of estuary and keep it available throughout the activity. Check back throughout the different exercises and have students continue to revise and improve their estuary definition.
4. Use the presentation, *Estuary Landforms and Features*, to help the students compare and contrast the different types of estuaries.
5. Distribute copies of the Student Master: *Just What Are Estuaries?* including the two resource sheets. Have students read the directions on the Student Master and then answer the questions. Possible answers to the questions are provided below. For additional resources on how to classify estuaries by geology visit: http://oceanservice.noaa.gov/education/tutorial_estuaries/est04_geology.html

Materials

- *Test Your Estuarine Wisdom* (student quiz)
- *What is an Estuary?* (online video)
- *Estuary Landforms and Features* (presentation)
- Student Master: *Just What Are Estuaries?*

Questions and Possible Answers

Q1. Is Mobile Bay, Alabama located on a coast? If yes, what large body of water is that coast on?

Yes, Mobile Bay is located on a coast. Mobile Bay is located along the Gulf coast of Alabama. The large body of water is the Gulf of Mexico.

Q2. Can you find evidence that fresh water enters Mobile Bay? List any evidence that you can see.

Fresh water enters Mobile Bay from the surrounding watershed. Students should point out that there are many rivers on the map that empty fresh water from the land into Mobile Bay.

Q3. Can you find evidence that salt water is entering the bay? List any evidence that you can see.

The mouth of Mobile Bay opens to the Gulf of Mexico, which is part of the world ocean. Water entering Mobile Bay from the Gulf of Mexico is salt water.

Q4. Do you think Mobile Bay is an estuary? Support your answer with estuary facts.

Yes. Mobile Bay is an estuary. Mobile Bay is a semi-enclosed body of water that has salt water entering it from the Gulf of Mexico and fresh water entering from rivers.

Q5. Now examine the shoreline inside Mobile Bay and see if you can find another, smaller estuary. Name the estuary and describe the features you think makes it an estuary.

The smaller “sub-estuary” is named Weeks Bay. Weeks Bay is an estuary because it has fresh water entering from the Magnolia and Fish Rivers. It has salt water entering through the mouth of Weeks Bay from Mobile Bay.

Q6. Name the four main types of estuaries.

Coastal plain estuary, tectonic estuary, bar-built estuary, and fjord

Q7. Look back at the Resource: Map of Mobile Bay, Alabama. What type of estuary is Mobile Bay? What type of estuary is Weeks Bay?

Mobile Bay is a coastal plain estuary. Weeks Bay is also a coastal plain estuary.

Q8. Look at the photo on Resource: What Kind of Estuary Is This? Identify which type of estuary is shown in the photo.

Jobos Bay, NERR PR is a bar-built estuary. Students should mention that they see a shallow lagoon or bay that is protected from the ocean by a sandbar or barrier island.

STUDENT MASTER

Just What Are Estuaries?

Estuaries are areas of transition where fresh water and salt water meet. An estuary is a partially enclosed coastal embayment (or bay) where fresh water and salt water from the ocean mix. For that mixing to occur, there must be an opening from the estuary to the ocean for at least part of the year. That lets salt water from the ocean enter the estuary. Most of today's estuaries formed because the sea level of Earth's global ocean has slowly risen over the last 18,000 years, drowning river valleys and filling in glacial troughs.

Some unique Great Lakes coastal wetlands are referred to as freshwater estuaries. They occur where rivers and Great Lakes water mix in shallow wetlands located near the mouth of a river.

Procedure

1. Use Resource: *Map of Mobile Bay, Alabama* to answer the following questions.
 - Q1. Is Mobile Bay, Alabama located on a coast? If yes, what large body of water is that coast on?

 - Q2. Can you find evidence that fresh water enters Mobile Bay? List any evidence that you can see.

 - Q3. Can you find evidence that salt water is entering the bay? List any evidence that you can see.

 - Q4. Do you think Mobile Bay is an estuary? Support your answer with estuary facts.

 - Q5. Now examine the shoreline inside Mobile Bay and see if you can find another, smaller estuary. Name the estuary and describe the features you think makes it an estuary.

2. Use Resource: *The Four Types of Estuaries* to answer the following questions.
 - Q6. Name the four main types of estuaries.

 - Q7. Look back at Resource: *Map of Mobile Bay, Alabama*. What type of estuary is Mobile Bay? What type of estuary is Weeks Bay?

 - Q8. Look at the photo on Resource: *What Kind of Estuary Is This?* Identify which type of estuary is shown in the photo.

TEACHER MASTER

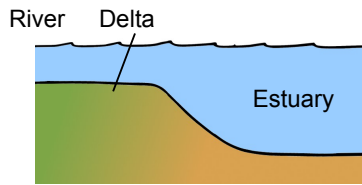
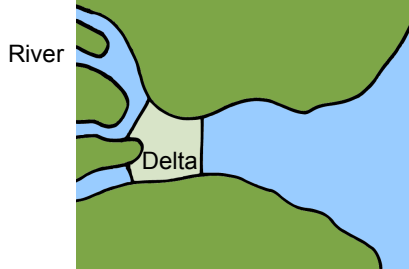
Map of Mobile Bay, Alabama



TEACHER MASTER

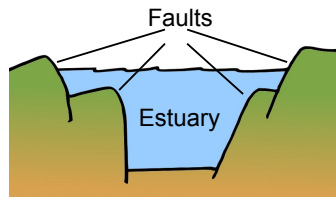
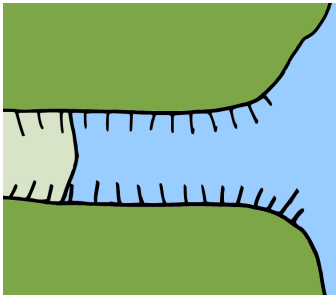
The Four Types of Estuaries

1. **Coastal plain estuaries** are formed when sea level rises, flooding existing river valleys. This type of estuary contains a delta. A delta is a low-lying sediment deposit found at the mouth of a river.



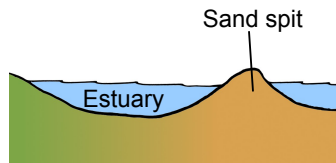
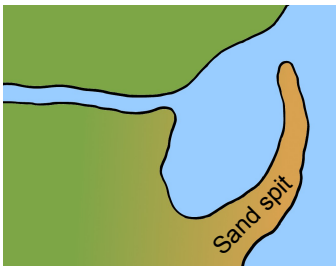
Profile view

2. **Tectonic estuaries** are created when a piece of the Earth's crust cracks, sinks or subsides and produces a depression or basin below seal level that fills with water. These kinds of estuaries are often occur along lines during earthquakes.



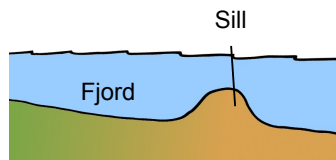
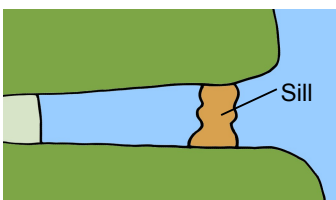
Profile view

3. **Bar-built estuaries** form when a shallow lagoon or bay is protected from the ocean by a sand bar or barrier island.

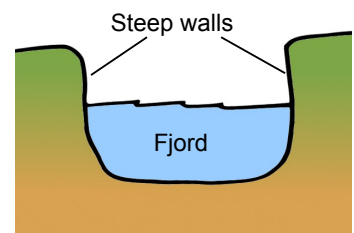


Profile view

4. **Fjords** are U-shaped valleys carved out by glacial erosion. Fjords are found in areas with long histories of alpine (valley) glacier activity.



Profile view



Adapted from ONR Office of Naval Research: Oceanography Habitats: Estuaries Characteristics

TEACHER MASTER

What Type of Estuary Is This?



Jobos Bay National Estuarine Research Reserve, Puerto Rico

EXERCISE 2

One Ocean, Many Estuaries

Estuary Concept

Because estuaries are interconnected with the world ocean, changes in sea level or ocean temperature are certain to affect estuaries world-wide.

Focus Questions

- How are estuaries interconnected with the world ocean?
- How could long term changes in ocean temperature affect estuaries?

Performance Tasks

Students will:

- Identify where Earth's estuaries are located.
- Use data from a sea surface temperature map to examine where the temperatures of ocean water are warmest or coolest near estuaries.

Teacher Background

If you look at Earth as a whole, it is obvious that the oceans of the world are connected. There is only one global ocean. The seas are geographically divided into the Atlantic, Pacific, Indian, Arctic, and Southern (Antarctic) Oceans. But these five oceans are not separate bodies of water. The boundaries are artificial and have arisen for a variety of historical, cultural, geographical, and scientific reasons.

By definition, an estuary is open to the sea. That means that all estuaries are affected by changes in the one global ocean. Even the estuaries on the Great Lakes are connected by canals to the Atlantic Ocean. If sea level rises globally, then the water level within all of the world's estuaries rises as well. If the temperature of the global ocean water near the ocean's surface slowly rises, then the temperature of water within the estuaries slowly rises as well.

However, just because there is one global ocean does not mean that the water is the same at all locations. Ocean water temperature, for example, is affected by air temperature, which is determined by those things that determine weather and climate: latitude, seasonal changes in solar energy, winds, etc. Ocean water temperature at a given location is also affected by surface and deepwater currents within the ocean. Ocean water chemistry also varies within this one global ocean. At a given location, the particular properties of the ocean water outside the estuary and entering the estuary affect the properties of the water within the estuary.

The water in the estuary is also affected by the water that enters the estuary from rivers and streams. Seasonally, spring rains and floods should be expected to increase the flow of fresh water into the estuary, lowering the water salinity. Droughts inland would have the opposite effect as decreases in fresh water entering the estuary would lead to increased water salinity.

Overview

In this exercise, students will explore where estuaries are located worldwide. Wherever the ocean meets the land, there exists the possibility of an estuary. Students also explore how geographic location can affect sea water temperature which, in turn, affects the water temperature within estuaries at that location.

Time Required

One 45-minute class session

Climate Extension

The ocean's capacity to absorb and redistribute large amounts of solar energy makes it an important climate regulator. By moving excess heat at the equator towards the poles and cold towards the equator, the ocean works with the atmosphere to balance the uneven heating of the Earth by the Sun. Much of the surface heat of the oceans is moved by wind-driven currents that can be monitored through satellite maps of the Sea Surface Temperature.

One of the major indicators of global climate change has been the discovery of an overall increase in ocean temperature. A continued increase in air and ocean temperature could lead to changes in ocean circulation and dramatically impact the marine environment on local and global scales. The effect of the increase on coastal water and air temperature in estuaries is complex. Estuaries that have a small tidal range are more likely to be impacted by the changes in air temperature than the temperature of the coastal ocean. However, tidally well-flushed estuaries will more likely be driven by coastal ocean temperatures. The increase in coastal water temperature and the air temperature due to climate change would have many consequences to the estuary ecosystem including: heat stress on estuary organisms, shifts in migration routes, shifts in the types of plants that make up the habitat, shifts in when phytoplankton and other primary producers bloom, reduction of ice formation, lower dissolved oxygen and other impacts to water quality.

Teacher Preparation

1. Review all parts of the Student and Teacher Masters to become familiar with their use. Students will be using the Student Master: *World Estuary Map* to determine whether different locations are places where estuaries occur or not. You will want to be prepared to use a projector to display the *World Estuary Map* to discuss with students in the first part of this exercise.
2. Because of the necessity for students to see the sea surface temperature map in color, you may want to be prepared to use a projector to show your students the Teacher Master: *Sea Surface Temperature* map. Explain to students that this is a “false” color map designed to make it easier to see the different sea surface temperatures. A map showing the “true” color of the oceans would not look the same. You may choose to make black-and-white copies of the Teacher Master: *Sea Surface Temperature* and still project the color version of the map for students reference as they are completing work on the Student Master: *One Ocean, Many Estuaries*.
3. Make copies of Student Master: *One Ocean, Many Estuaries* for each student.
4. Make copies of Student Master: *World Estuary Map*.
5. Teacher Master: *Celsius vs. Fahrenheit* is provided if you feel that your students need to review the relative temperatures of the two scales. Much of the work in the Estuary 101 Curriculum uses Celsius.

Procedure

1. Project the Student Master: *World Estuary Map* for your students. Have your students look at the different geographically-named oceans (i.e., Pacific Ocean, Atlantic Ocean). Are these oceans really separate or are they joined together to form one global ocean? Students should see that the separate named oceans are connected and make up one ocean.
2. Now discuss the locations of the estuaries shown as dots on the map. Where are the estuaries located? Students should see that estuaries are located in coastal areas all over the map. Ask your students if they think the map is showing all of Earth's estuaries. Students should realize that not all estuaries are shown on this map. If you were to zoom in on any particular coastal area, you might find an estuary wherever a river enters the sea.
3. Review latitude and longitude with your students. Ask your students to take turns picking different places on the map and describing their locations using latitude and longitude coordinates.
4. Students should now use Student Master: *World Estuary Map* to examine the latitude and longitude of locations listed in the table on the Student Master: *One Ocean, Many Estuaries*. Students decide if each location is an estuary or not.
5. Help your students locate the Amazon River. Find where the Amazon River enters the Atlantic Ocean along the coast of Brazil. Students should record the latitude and longitude of the river's mouth.
6. Next help your students examine the false color map from the Teacher Master: *Sea Surface Temperature*. Again, you may want to project your color copy of the map for student use. Show students the color key and how to use the key to interpret different sea surface temperatures.
7. Have the students locate the Amazon River mouth on the sea surface temperature map. Does the ocean water outside the river's mouth appear to be warmer or cooler than the surrounding ocean water?
8. Students then answer the remaining questions on. Student Master: *One Ocean, Many Estuaries*. Possible answers are shown below.

Climate Extension

9. Return the Teacher Master: *Sea Surface Temperature* false color map from September 2009 to the projector. In small groups, have the students discuss the relationship between how the ocean's water moves and the Sea Surface Temperature.
10. On the Student Master: *World Estuary Map*, have the students draw arrows indicating the movement of the major ocean currents. Students can use blue markers or pencils to indicate cold currents and red markers or pencils to indicate warm currents.
11. Next place the Teacher Master: *World Ocean Current Map* on the projector and have the students compare their arrows to the world currents. Were there any unexpected differences in their maps and the world ocean current map?
12. Then project the Teacher Masters: *Sea Surface Temperature September 1989 and 2009* side to side. Ask the students to describe the differences in the

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

Per student

- Student Master: *One Ocean, Many Estuaries*
- Student Master: *World Estuary Map*
- Teacher Master: *Celsius vs. Fahrenheit*
- Teacher Master: *Sea Surface Temperature*

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>.



maps. Which map looks like it has higher overall sea surface temperature? Ask the students why these two maps are not enough to prove the climate change? What more data would scientists need to demonstrate the impacts of climate change on Sea Surface Temperature?

13. To wrap-up the classroom discussion, show the 2 minute NOAA visualization titled “Heating up the Ocean” found online in the Climate Tab for this activity.
14. Individually or in small groups, have students answer the climate extension questions.

Questions and Possible Answers

For the following map locations, students should circle the coordinates shown below in **bold**. Those are estuaries.

35° N, 147° W (Japan)	65° N, 160° W (N. Alaska)
16° N, 100° W (Mexico)	46° N, 70° W (Great Lakes)
40° S, 150° E (Australia)	51° N, 0.5° E (United Kingdom)
20° S, 70° W (South America)	70° N, 50° W (Greenland)

Q1. Use the World Estuary Map to locate the mouth of the Amazon River in northeast South America. Record the latitude and longitude.

0° N, 50° W

Q2. Water found in estuaries at latitude 0° is always warm. Why do you think that’s true?

Zero degrees latitude is the equator. Both air and water temperatures are warm year round at the equator. The maps show the warmest ocean water is near the equator. Fresh water entering the estuary from the land is more likely to be warm at the equator and will be all year. Mixing warm ocean water with warm fresh runoff leads to warm water in the estuary itself.

Q3. Do you think that the water temperatures are the same for every estuary on Earth, no matter its location? Why or why not?

Both ocean water and fresh water runoff are likely to be much colder at higher latitudes than the same water sources near the equator. For this reason, the water within the estuary, which is a combination of the two water sources, should vary from location to location based on latitude, currents along the shore, and even seasonal factors affecting water temperature of runoff.

Q4. What is the relationship between ocean water temperature and estuary water temperature?

Generally, since the water from the ocean enters the estuary with the tides and mixes with the water that is already in the estuary and with fresh water entering the estuary from rivers and streams, the warmer the ocean water temperature, the warmer the estuary water should be.

Climate Extension

Q5. What clues on the Sea Surface Temperature maps helped you decide how the ocean water is moving?

Students should describe how they used the bands of warmer moving across the equator as well as warmer and cooler bands along the continental margins as clues to understand how the currents were moving.

Q6. Where on the Earth are ocean water movements carrying heat towards the poles? Where are the currents bringing cool water towards the equator?

There could be several answers to this question. In the Pacific Oceans the students should highlight the currents taking warm water from the equator up the eastern side of the ocean past Japan, as well as down the western side of Australia to the South Pole. On the west side of the Pacific Ocean cool water is brought down the west side of North America and up the west side of South America

Q7. If global climate change continues, predict how the Sea Surface Temperature maps might look in the year 2109?

If the climate continues to warm the Earth then the Sea Surface Temperature will also increase, resulting in maps that represent larger areas of warmer water on the map. This would mean that most likely there would be larger areas around the equator with red, and orange colors representing the warm temperature. Most likely the areas with the coldest temperatures, represented in purples will also decrease dramatically as well, although that might depend if there is major ice melt during that time.

Q8. How could warming ocean temperature impact the estuary ecosystem?

Since estuaries are where saltwater from the ocean mix and meet freshwater, warming of ocean temperatures would most likely mean that the estuary temperature would also increase. The degree of the warming would depend on the type of the estuary. The impact of warmer temperatures within the estuary would pose a variety of threats to marine organisms living in the estuary, could impact the dissolved oxygen levels, and other water quality

parameters. Warming ocean temperatures could also change coastal currents.

Q9. How might the influence of ocean temperatures on estuaries vary between a tidally well-flushed estuary and an estuary with little tidal flushing?

Estuaries that have a small tidal range are more likely to be impacted by the changes in air temperature than the temperature of the coastal ocean. This is because the air and incoming freshwater temperature define the estuary more than ocean water. However, tidally well-flushed estuaries will more likely be impacted by change in coastal ocean temperature.

STUDENT MASTER

One Ocean, Many Estuaries

Look at a globe. What color do you see the most of on the globe's surface? Earth looks pretty blue, doesn't it? That's because 71% of Earth's surface is covered with water and most of that is ocean. The Pacific Ocean is connected to the Indian Ocean on one side and the Atlantic Ocean on the other. The Arctic and Southern Oceans are connected to both the Atlantic and Pacific oceans. There is really only one global ocean.

Wherever rivers from the land meet the ocean or sea, there is the possibility that conditions will support the formation of an estuary. If fresh water from rivers can meet the salt water from the ocean in a semi- enclosed location, then you will find an estuary.

Procedure

1. Take a look along the coastlines of the world's continents on the Student Master: *World Estuary Map*. Find the dots, which represent some estuary locations.
2. Look at the latitude and longitude coordinates in the table below. These coordinates are for locations that may or may not be estuaries. Use the *World Estuary Map* to determine if an estuary exists at the locations listed in the table. Circle the location's coordinates in the table if you think that location is an estuary.

Location	
35° N, 147° E (Kanagawa, Japan)	65° N, 160° W (N. Alaska)
16° N, 100° W (Mexico)	46° N, 70° W (Great Lakes)
40° S, 150° E (Australia)	51° N, 0.5° W (United Kingdom)
20° S, 70° W (South America)	70° N, 50° W (Greenland)

3. Use the Student Master: *World Estuary Map* and the Teacher Master: *Sea Surface Temperature* to answer the following questions.

Questions

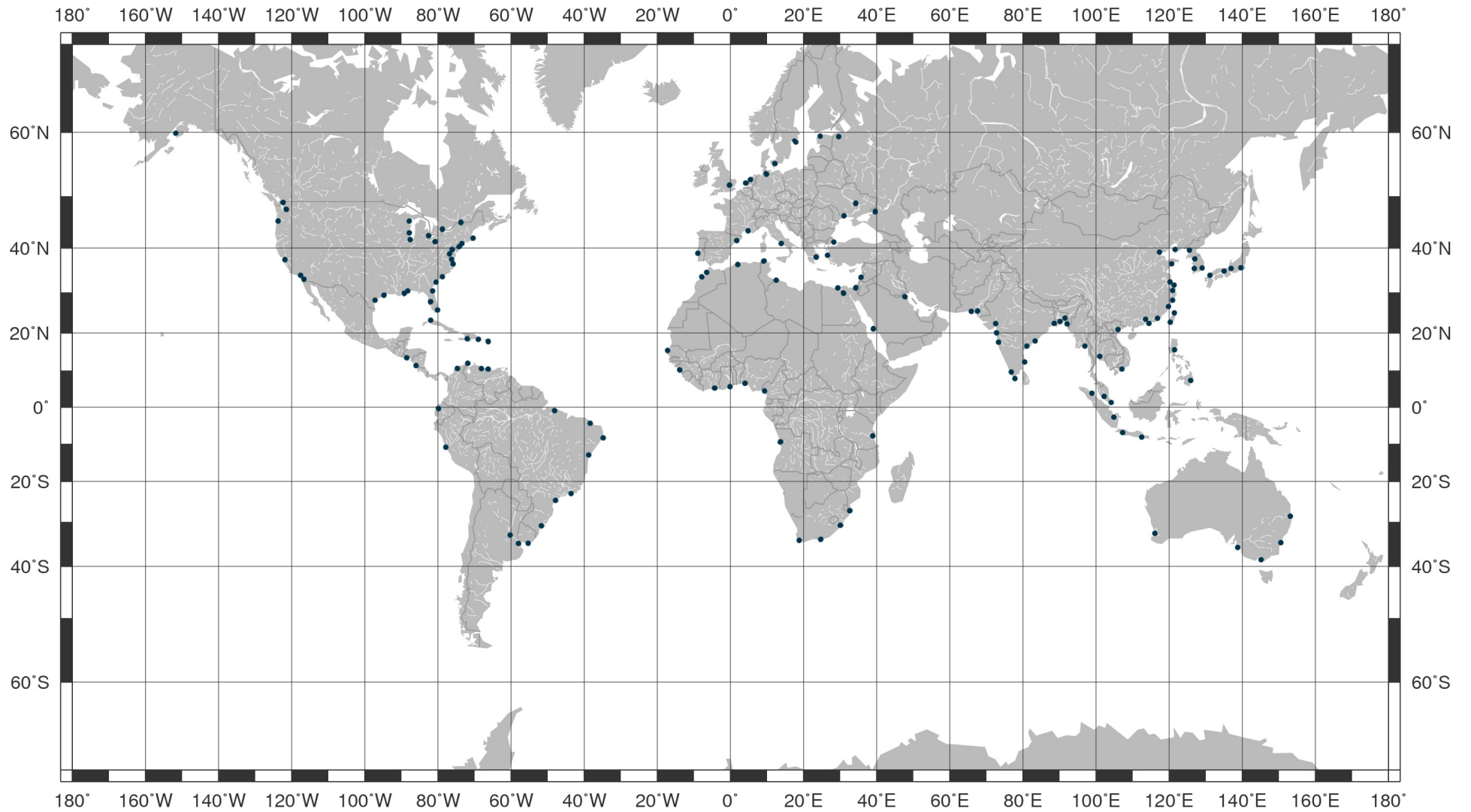
- Q1. Use the World Estuary Map to locate the mouth of the Amazon River in northeast South America. Record the latitude and longitude.
- Q2. Water found in estuaries at latitude 0° is always warm. Why do you think that's true?
- Q3. Do you think that the water temperatures are the same for every estuary on Earth, no matter its location? Why or why not?
- Q4. What is the relationship between ocean water temperature and estuary water temperature?

Climate Extension

- Q5. What clues on the Sea Surface Temperature maps helped you decide how the ocean water is moving?
- Q6. Where on the Earth are ocean water movements carrying heat towards the poles? Where are the currents bringing cool water towards the equator?
- Q7. If global climate change continues, predict how the Sea Surface Temperature maps might look in the year 2109?
- Q8. How could warming ocean temperature impact the estuary ecosystem?
- Q9. How might the influence of ocean temperatures on estuaries vary between a tidally well-flushed estuary and an estuary with little tidal flushing?

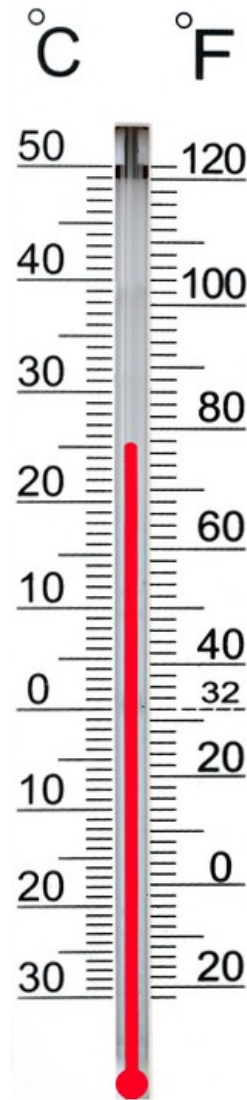
STUDENT MASTER

World Estuary Map



TEACHER MASTER

Celsius vs. Fahrenheit



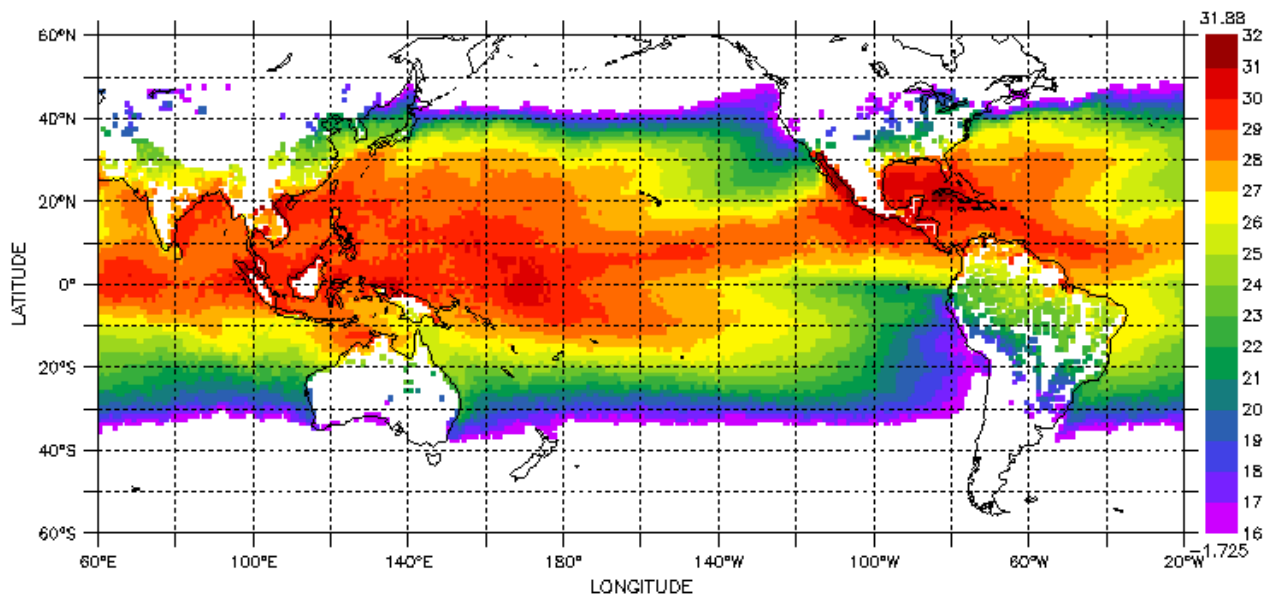
TEACHER MASTER

Sea Surface Temperature

LAS 7.3/Ferret 6.72 NOAA/NODC

TIME : 15-SEP-2009 06:57

DATA SET: AVHRR Pathfinder SST V5



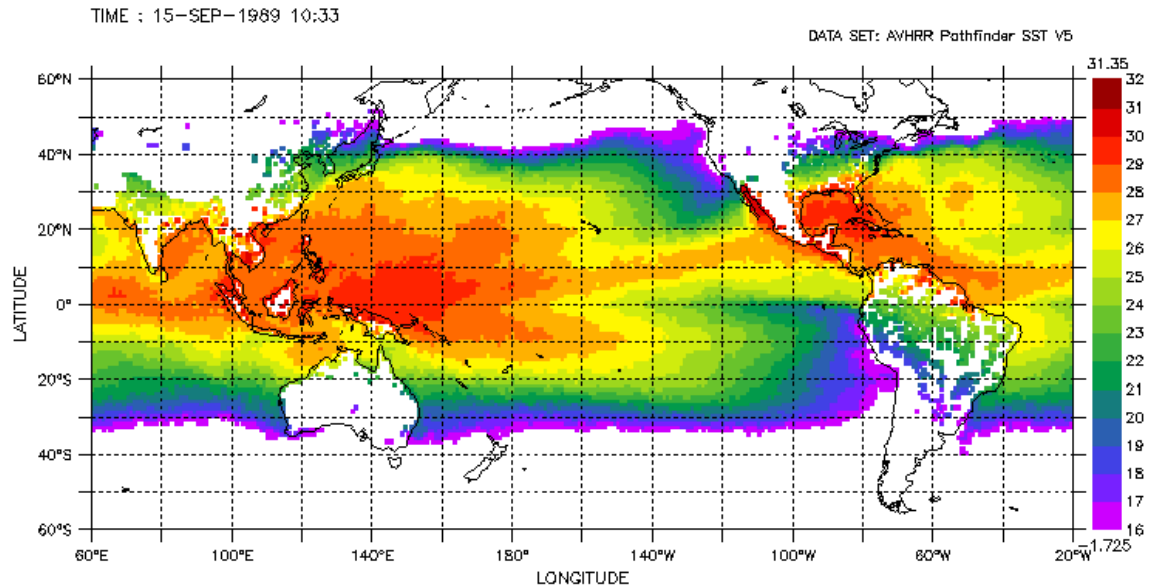
Sea Surface Temperature mixed night and day: monthly, One Degree, quality flag 4 (degrees Celsius)

TEACHER MASTER

Sea Surface Temperature Maps

September 1989

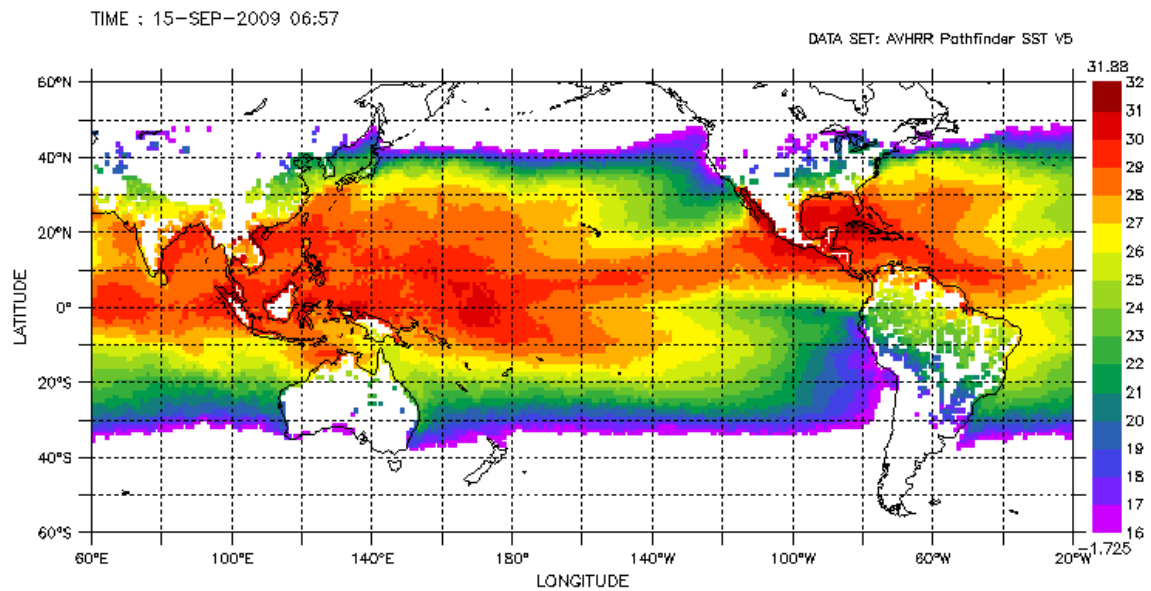
LAS 7.3/Ferret 6.72 NOAA/NODC



Sea Surface Temperature mixed night and day: monthly, One Degree, quality flag 4 (degrees Celsius)

September 2009

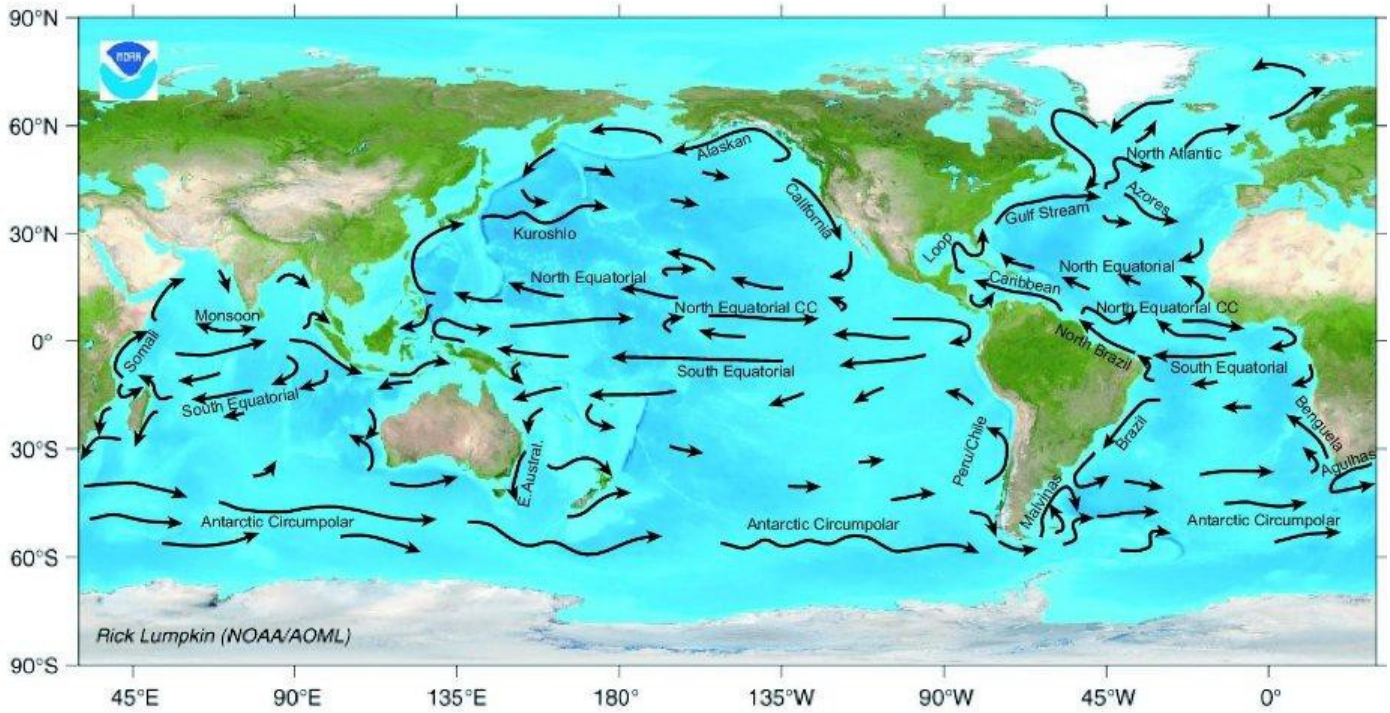
LAS 7.3/Ferret 6.72 NOAA/NODC



Sea Surface Temperature mixed night and day: monthly, One Degree, quality flag 4 (degrees Celsius)

TEACHER MASTER

World Ocean Map



EXERCISE 3

Explore Estuaries in the NERR System

Estuary Concept

The mission of NERRS is to practice and promote coastal and estuarine stewardship through innovative research and education, using a system of protected areas.

Focus Question

How does the National Estuarine Research Reserve System (NERRS) act as stewards of our nation's estuaries?

Performance Tasks

Students will:

- Locate each NERRS estuary on an interactive map and find which type of estuary it is.
- “Adopt” one Reserve for further study and create a travel brochure about that Reserve.
- Present their travel brochure about their “adopted” Reserve to the class.

Teacher Background

There are 28 estuarine reserve sites that make up the National Oceanic and Atmospheric Administration's (NOAA) National Estuarine Research Reserve System (NERRS). These sites are located in 22 of the 35 U.S coastal states from Alaska to Puerto Rico, including the Great Lakes Basin, and protect over 1.3 million acres of coastal land and waters.

What is NERRS? NERRS is a partnership program between NOAA and the coastal states. The areas within the reserves, including valuable estuaries, are protected for long-term research, water-quality monitoring, education, and coastal stewardship. Twenty-three of the reserves have Environmental Learning and Interpretation Centers which, in several cases, include research laboratories, classrooms, auditoriums, and visitor centers. Reserves with these Centers generally offer a variety of hands-on experiences and interactive exhibits which address research and stewardship efforts in the reserve.

The NERRS reserves are amazing and beautiful areas to visit. But you can also connect to them virtually via the Estuaries 101 site. The National Estuarine Research Reserves are not only a system of protected estuaries. They are national treasures.

Overview

Students need to understand that estuaries are important to all of us. In fact, estuaries are so important that a state-federal partnership was established to promote research, education, and coastal stewardship at designated estuary reserves around the country. This group of estuary reserves is called the National Estuarine Research Reserve (NERR) System. In this exercise, students first look at the entire NERR System by visiting Reserves using an online interactive map. Students then adopt a NERR site and research that Reserve estuary. Students present their findings to the class in the form of a travel brochure.

Time Required

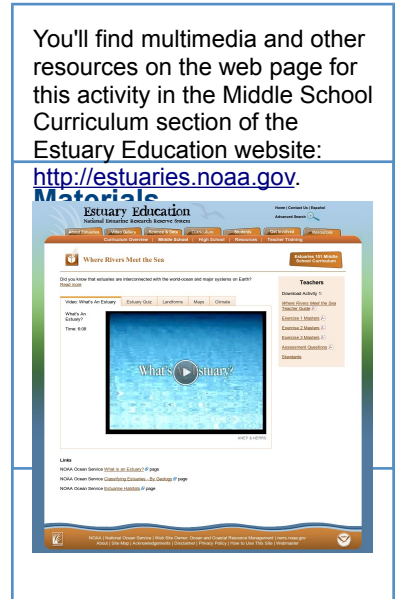
Two 45-minute class session and homework time

Teacher Preparation

1. Become familiar with the NERRS *Interactive Map* in the Middle School Curriculum section of estuaries.noaa.gov. Click on different Reserve sites to see the type of data students will be seeing when they use the Interactive Map in this and later activities.
2. Read the Student Master: *Explore Estuaries in the NERR System* to become familiar with the information students are being asked to include in their NERR travel brochure.

Procedure

1. Explain to students why it is important to have a partnership such as the National Estuarine Research Reserve to provide stewardship for the estuaries in the United States. Share additional information about NERRS from the Teacher Background as needed.
2. Give a copy of Student Master: *Explore Estuaries in the NERR System* to each student or team of two students. Have your students follow the directions on the Student Master and use the NERRS Interactive Map to identify a reserve they want to build a travel brochure for.



NERRS Reserve Sites & Estuary Types ANSWERS	
<p>Northeast</p> <p>Wells NERR, ME – Coastal Plain Great Bay NERR, NH – Coastal Plain Waquoit Bay NERR, MA – Bar-built/Coastal Plain Narragansett Bay NERR, RI – Coastal Plain Hudson River NERR, NY – Coastal Plain/Fjord</p>	<p>Great Lakes</p> <p>Old Woman Creek NERR, OH – Coastal Plain Lake Superior NERR, WI – Coastal Plain</p>
<p>Mid Atlantic</p> <p>Jacques Cousteau NERR, NJ – Coastal Plain Delaware NERR, DE – Coastal Plain Chesapeake Bay NERR, MD – Coastal Plain Chesapeake Bay NERR, VA – Coastal Plain</p>	<p>Gulf of Mexico</p> <p>Rookery Bay NERR, FL – Bar-built/Coastal Plain Apalachicola NERR, FL – Coastal Plain /Delta System Weeks Bay NERR, AL – Coastal Plain Grand Bay NERR, MS – Coastal Plain /Delta System Mission-Aransas NERR, TX – Coastal Plain</p>
<p>Southeast</p> <p>North Carolina NERR, NC – Bar-built/Coastal Plain North Inlet-Winyah NERR, SC – Bar-built/Coastal Plain</p>	<p>West Coast</p> <p>Kachemak Bay NERR, AK – Fjord Padilla Bay NERR, WA – Delta System/Fjord South Slough NERR, OR – Coastal</p>

ACE Basin NERR, SC – Bar-built Sapelo Island NERR, GA – Bar-built GTM NERR, FL – Bar-built	Plain/Tectonic San Francisco NERR, CA – Tectonic Elkhorn Slough NERR, CA – Tectonic/Coastal Plain Tijuana River NERR, CA – Bar-built
Caribbean Jobos Bay NERR, PR – Bar-built	

- Next, explain to students that they are to create a travel brochure on an estuary reserve of their choice. They should do their research online using the Estuaries 101 NERRS *Interactive Map* and identify reasons why classmates might want to visit. Review the directions on the Student Master. Travel brochures will benefit from photos and information about such things as plant and animal life found in the estuary, descriptions of unique characteristics, recreational uses, etc. This type of information may be found outside of the Estuaries 101 NERRS *Interactive Map*. Have students start by visiting estuaries.noaa.gov. You may want to help students choose Reserves from different parts of the NERR System so that the class reports are varied.
- Have your students present their brochures to the class. Make sure each student or team uses a map to show the class where their Reserve is located.

STUDENT MASTER

Explore a NERR

It's your job in this exercise to "adopt" one of the National Estuarine Research Reserve System (NERRS) estuaries. Learn as much as you can about your Reserve and then make a travel brochure to present to your class about what makes your Reserve unique and why students might want to travel there.

Procedure

1. First you need to choose a reserve. Pick one of the sites listed below. Then, use the Estuary 101 NERRS *Interactive Map* to virtually visit your estuary site in the NERR System. Click on the NERR site location and use the information you find to identify what geographic type of estuary is located at that NERR Reserve estuary. Remember, the four types are: coastal plain, bar-built, tectonic, and fjord. What type of estuary are you reporting on.

NERRS Reserve Sites and Estuary Types	
<p>Northeast</p> <p>Wells NERR, ME _____</p> <p>Great Bay NERR, NH _____</p> <p>Waquoit Bay NERR, MA _____</p> <p>Narragansett Bay NERR, RI _____</p> <p>Hudson River NERR, NY _____</p>	<p>Great Lakes</p> <p>Old Woman Creek NERR, OH _____</p> <p>Lake Superior NERR, WI _____</p>
<p>Mid Atlantic</p> <p>Jacques Cousteau NERR, NJ _____</p> <p>Delaware NERR, DE _____</p> <p>Chesapeake Bay NERR, MD _____</p> <p>Chesapeake Bay NERR, VA _____</p>	<p>Gulf of Mexico</p> <p>Rookery Bay NERR, FL _____</p> <p>Apalachicola NERR, FL _____</p> <p>Weeks Bay NERR, AL _____</p> <p>Grand Bay NERR, MS _____</p> <p>Mission-Aransas NERR, TX _____</p>
<p>Southeast</p> <p>North Carolina NERR, NC _____</p> <p>North Inlet-Winyah NERR, SC _____</p> <p>ACE Basin NERR, SC _____</p> <p>Sapelo Island NERR, GA _____</p> <p>GTM NERR, FL _____</p>	<p>West Coast</p> <p>Kachemak Bay NERR, AK _____</p> <p>Padilla Bay NERR, WA _____</p> <p>South Slough NERR, OR _____</p> <p>San Francisco NERR, CA _____</p> <p>Elkhorn Slough NERR, CA _____</p> <p>Tijuana River NERR, CA _____</p>
<p>Caribbean</p> <p>Jobos Bay NERR, PR _____</p>	

2. Make a travel brochure for that NERR estuary. Use your travel brochure to try and persuade your classmates to travel there.

3. Gather information about your NERR site. Use the Estuaries 101 NERRS *Interactive Map* to find more information. Then click through to that Reserve's data page to read about your Reserve. Use the below ideas to guide you to identify interesting information to put in your brochure.
 - What is your Reserve's name? When did your Reserve become part of NERRS?
 - Where is your Reserve located? You may want to include a copy of your Reserve's location map from the website in your brochure.
 - Describe your Reserve's estuary. How does it fit the definition of an estuary? What type of estuary is it (i.e., coastal plain, fjord, bar-built, or tectonic)? In which bio-geographic region is your estuary located?
 - Your teacher will give you further instructions on the use of additional online or outside resources. If time allows, you may want to include information about life in the Reserve's estuary, how people use the estuary, features that make that estuary unique, and so on.
4. Be prepared to present your NERR travel brochure to your class. Make your presentation lively and engaging. Let your classmates know why you think they would enjoy visiting your Reserve estuary.

Conclusion

Based on the other Reserve travel brochures presented in class, how does your Reserve estuary compare to other Reserve estuaries in the NERR system?