Estuaries: Where Rivers Meet the Sea *Chapter* 14

	Pacing	Main Idea and Key Questions	Ocean Literacy Standards	Labs and Activities
14.1 Origins and Types of Estuaries	1 day	**There are four main types of estuaries, based on how they formed.** 1. What are estuaries? 2. How do estuaries differ between the Atlantic and Pacific coasts of North America?	1.d, 1.g, 2.b, 2.d, 2.e, 5.j	*TM Key Questions Activity*: Origins and Types of Estuaries p. 11
14.2 Physical Characteristics of Estuaries	2 days	**Estuaries have wide fluctuations in salinity and dissolved oxygen, and contain various types of sediments.** 1. How does salinity change with depth and distance from the ocean in an estuary? 2. What is a salt wedge? 3. How do suspended sediments in estuaries affect water quality and the type of organisms living there?	1.c, 1.g, 5.g	*TM Key Questions Activity*: Physical Characteristics of Estuaries p. 12 *Laboratory Manual*: Activity 14.1 Watershed Mapping
14.3 Estuaries as Ecosystems	2 days	**There are four main types of estuarine communities, each with organisms specially adapted to live there.** 1. What challenges do organisms living in estuaries face? 2. What are pneumatophores? 3. Within estuaries,	5.*b*, 5.*g*, 5.*i*, 5.*j*, 6.*b*	*Student Edition*: p. 431 in–text feature "Fiddler on the Mud" (see attached Inquiry Activity on sexual dimorphism p. 19). *TM Key Questions Activity*: Estuaries as Ecosystems p. 12 *Laboratory Manual*: Activity 14.2 Wetland in a Pan

		what is the main form of organic material that is available to consumers?		
14.4 Human Impact on Estuarine Communities	1 day	**Estuaries provide many important functions, both to the marine environment and to humans, which are lost and when humans impact estuaries by dredging or filling them.** 1. What are the ecosystem services of estuaries? 2. How much of estuaries have been lost worldwide due to human activities?	5.*b*, 5.*g*, 6.*b*, 6.*c*, 6.*e*, 6.*g*	*Student Edition*: p. 445 in−text feature "Restoration of Salt Marshes" (see attached Inquiry Activity on restoration of salt marshes p. 24). *TM Vocabulary Review Activity* p. 10 *TM Key Questions Activity*: Human Impact on Estuarine Communities p. 13 *TM Chapter Project*: Snapshot of an Estuary, p. 15

Chapter Summary

Section 14.1

The Big Idea for Chapter 14 hints at the uniqueness and importance of the estuaries discussed in this chapter because of their great productivity, role in protection of shores as well as of coral reefs, and role as nursery for many species. While called a variety of names, all estuaries are situated at the interface of land and ocean, where freshwater and saltwater meet and mix, and the impacts of man are close−at−hand. Estuaries are typically classified based on their origins, as estuaries are the resulting feature of a number of geologic changes such as retreating glaciers, sea−level rising, land sinking, and sediment accumulation building up sand bars and barrier islands.

Section 14.2

Physical characteristics of estuaries vary temporally and geographically, and organisms living in estuaries must be able to survive the regular fluctuations of the physical characteristics of their habitat. Salinity tends to increase downstream and with depth, and is influenced by seasonal rainfall, evaporation rates, tides and currents. Likewise, water temperatures in estuaries vary greatly with daily and seasonal fluctuations. Flow of water in estuaries influences levels of oxygen in the water column and within the substrate, so that some estuaries have anoxic, muddy floors, while others have oxygen−rich waters. Clay and suspended particles greatly decrease the clarity of the water in many estuaries. Hands−on demonstrations of the Coriolis Effect or the utilization of other resources are recommended to aid in explaining this particular phenomenon that is often found to be confusing to students.

The few organisms living in estuarine ecosystems address challenges in their rapidly changing conditions through a variety of adaptations. For example, drastic fluctuations in salinity can be avoided by organisms living in the muddy substrate, while organisms in the water column address this challenge through osmoregulation (like bony fishes) or osmoconformation (like molluscs). Salt marsh plants have adapted to highly saline environments through a variety of mechanisms such as the ability to excrete excess salts through glands, or to accumulate large amounts of water. Estuarine organisms that live in the anoxic mud substrate have adaptations for their environment, some of which allow them to survive for long periods of time without oxygen.

Section 14.3
Estuarine communities, with low biodiversity but high biomass, include those of the open water that come in and out with the tide, mudflats, salt marshes, mangrove forests, seagrass beds, and oyster reefs. Estuaries are critical at some point in the life cycle of most commercially−valuable species. Primary production by bacteria, archaea, benthic diatoms, and seaweeds can be abundant in all types of estuarine communities, while other types of primary producers, such as mangroves and seagrasses and salt marsh vegetation, consumers and predators can vary in number and variety depending on the physical characteristics associated with the estuary. Mangrove forests offer an opportunity to guide students into a unique, beautiful and intriguing habitat that is often unfamiliar to them.

Section 14.4
Anthropogenic threats to estuaries include dredging, filling, deforestation, damming and diverting of rivers and agriculture, which expose estuaries to invasive species, wave action, changes in amounts of freshwater inputs, and increases in sediment. This, in turn, can result in loss of shoreline and coral reefs. Mangrove forests have been further impacted by deforestation for timber and for agriculture and aquaculture, increased boat traffic and associated pollution. Sea level rising due to climate change and ocean warming is anticipated to have far−reaching impacts on salt marshes and mangrove forests. Educating communities on the high economic and ecological value of estuaries is emphasized as essential by conservation programs worldwide.

Activities
Key Questions Activities
These activities expand up the key questions from each section opener.
14.1 Origins and Types of Estuaries: Students will participate in a teacher−led discussion about what they know about estuaries and the organisms that live in them.

14.2 Physical Characteristics of Estuaries: Students will look at real−time data from five different estuaries, and compare and contrast current physical conditions.

14.3 Estuaries as Ecosystems: Students will discuss the economic and environmental benefits of estuaries. Students will also discuss as a group how to balance extractive or commercial uses of estuaries with protecting the integrity of the environment.

14.4 Human Impact on Estuarine Communities: Students will be divided into groups to discuss four different human impacts on estuaries: toxic pollution, eutrophication, pathogens, and invasive species. Students will research their assigned topic and present their findings to the class.

Vocabulary Review Activities
These activities help to ensure student understanding of the vocabulary presented in the chapter. Not every chapter has a corresponding Vocabulary Review Activity.

Feature Inquiry Activities
Fiddler on the Mud – Sexual Dimorphisms
In this activity, students will research and present on sexual dimorphisms in the marine environment.

Restoring Salt Marshes – Ditch those Mosquito Ditches
In this activity, students will research the history and consequences of constructing mosquito ditches in salt marshes along the Atlantic coast.

External Resources

NOAA Ocean Service Education Professional Development: *Estuaries*
http://oceanservice.noaa.gov/education/pd/estuaries/welcome.html
This resource for teachers offers in−depth resources on The National Estuarine Research Reserve System Collection, Estuary LIVE Video Gallery, Podcasts, and other resources for use in and out of the classroom.

Chapter Project

Snapshot of an Estuary
In this activity, students will research one of the 28 National Estuarine Research Reserve (NERR) sites. They will obtain real data from their NERR site, and graph and describe how the physical and chemical features of their estuary change over the course of a year.

Student Edition Review Question Answers

Section 14.1 *Review*

1. **Classify** Make a table to classify the different types of estuaries.

Type of Estuary	How It Formed	Examples
Drowned river valley	formed when sea level rose because of the melting of ice at the end of the last ice age, about 18,000 years ago; the sea invaded lowlands and river mouths in the process	Chesapeake Bay, mouth of Delaware River, bayous that are affected by tides along the low−lying mouth of the Mississippi River and adjacent coastal areas on the northern Gulf of Mexico, mouth of the St. Lawrence River in eastern Canada, and the mouth of the River Thames in England
Bar−built	the accumulation of sediments along the coast builds up sand bars and barrier islands that act as a wall between the ocean and fresh water from rivers	along the Texas coast of the Gulf of Mexico, the section of the North Carolina coast protected by the Outer Banks and Hatteras barrier islands, and along the North Sea coast of the Netherlands and Germany
Tectonic	created not because sea level rose but because the land sank, or subsided, as the result of movements of the crust	San Francisco Bay in California
Fjord	created when retreating glaciers cut deep, often spectacular, valleys along the coast; the valleys were partially submerged when sea level rose, and rivers now flow into them	common in southeastern Alaska, British Columbia, Norway, southern Chile, and the South Island of New Zealand

2. **Contrast** What are the differences in estuaries on passive margins versus those on active margins? [Broad, well−developed estuaries are particularly common in regions with flat coastal plains and wide continental shelves, a feature typical of passive margins. This is the case along the Atlantic coast of North America. The opposite is true for the steep coasts and narrow continental shelves of the Pacific coast of North America and other active margins. Here, narrow river mouths carved along the steep coast have restricted the formation of estuaries.]

Section 14.2 *Review*

1. **Relate** How are salt wedges and tidal rhythms related to fluctuations in salinity in estuaries? [The salt wedge moves back and forth with the daily rhythm of the tides. It moves up the estuary on the rising tide, then recedes as the tide falls. This means that organisms that stay in one place are faced with dramatic fluctuations in salinity. They are submerged under the salt wedge at high tide and under low−salinity water at low tide. If the area has a diurnal tide, the organisms are subjected to two shifts in salinity every day: one as the tide moves upstream and a second as it retreats. In an estuary with semidiurnal tides, salinity changes four times a day.]
2. **Describe** the substrate in estuaries and the organisms found there. [The substrate of most estuaries is sand or soft mud. Mud, which is actually a combination of silt and clay is rich in organic material. As in other organic−rich sediments, respiration by decay bacteria uses up oxygen in the interstitial water, the water between sediment particles. Water cannot easily flow through the fine sediments to replenish the oxygen supply. As a result, the sediments in estuaries are often devoid of oxygen, or are anoxic, below the first few centimeters. They have the black color and rotten−egg smell typical of anoxic sediments, in which hydrogen sulfide (H_2S), which is toxic to most organisms, accumulates. Anoxic sediments are not completely devoid of life. Anaerobic bacteria, which do not need oxygen to carry out respiration, thrive under these conditions.]

Section 14.3 *Review*

1. **Identify** What are some of the adaptations estuarine plants and animals have to manage the **fluctuations** in salinity? [Some animals adapt by simple changes in behavior. They may hide in their mud burrows, close their shells, or swim away if the salinity drops. Soft−bodied estuarine animals, such as many molluscs and polychaete worms, are osmoconformers. They maintain osmotic balance simply by allowing their body fluids to change with the salinity of the water. Many fishes, crabs, molluscs, and polychaetes are instead osmoregulators. They keep the salt concentration of their body fluids more or less constant regardless of the water salinity. When the salinity of the water is lower than that of the blood, they get rid of excess water and, via active transport, absorb some solutes from the surrounding water to compensate for those lost in the elimination of water. The gills, kidneys, and other structures accomplish this.]
2. **Summarize** What are the four main types of estuarine communities and the dominant organisms in each? [open water: plankton, fish, juveniles of marine species that breed at sea but use estuaries as nurseries, shrimps, crabs; mudflats: diatoms, bacteria, burrowing animals, such as worms, bivalves, crabs, snails; salt marshes: grasses and other salt−tolerant land plants; mangrove forests: mangroves are flowering land plants adapted to live in the intertidal zone]
3. **Explain** Why do estuaries have high primary production? [Nutrients brought in by the tide and rivers; together with those generated by nitrogen−fixing organisms and the decomposition of detritus; are used by plants, algae, and bacteria, the primary producers. Primary production is especially high in the communities that surround estuaries. The dense stands of cordgrass and other salt−marsh plants (or mangroves in the tropics) are particularly adapted to live on the mud and thus take advantage of the high concentration of nutrients in the sediments. The diatoms and bacteria in the mud and the phytoplankton in the water also contribute significantly to primary production.]

Section 14.4 *Review*

1. **Describe** How have human activities led to the reduction of estuaries worldwide? [All around the globe estuaries are being dredged to make marinas, artificial harbors, and seaports. Others are filled to create everything from industrial parks and urban development to garbage dumps. The dredging of navigation channels increases the exposure of estuaries to wave action, which often results in the destruction of salt marshes. Another problem in some estuaries is the reduction or elimination of normal freshwater input when rivers are dammed or diverted. Sediment input from rivers is decreased so that erosion of sediments by tides is not replenished. The opposite can also be a problem. Deforestation and agriculture brings about an increase in sediment, which in estuaries like Chesapeake Bay, decreases water quality and increases pollution. Oil spills can be particularly harmful to salt marshes, as evidenced by the 2010 *Deepwater Horizon* spill in the Gulf of Mexico. Wetlands along the Louisiana coast of the Gulf of Mexico have also been gradually eroded away as the result of the cutting of canals to install pipelines and haul oil–drilling equipment.]
2. **Relate** How might the reduction of mangrove forests affect global climate change? [Mangrove forests remove carbon dioxide (CO_2) from the atmosphere and trap an unusually high proportion of their primary production as organic carbon in the leaves and detritus that are deposited in the sediments. When the mangroves are destroyed, much of this trapped CO_2 is released back to the atmosphere when the organic matter decays. Mangrove deforestation accounts for an estimated 10% of all CO_2 emissions caused by deforestation, even though mangrove forests occupy only 0.7% of the area of tropical forests. The release of excess carbon dioxide into the atmosphere contributes to climate change.]

Chapter 14 *Review*

Multiple Choice

1. Estuarine organisms that are euryhaline [b]
   a. tolerate only a narrow range of salinities.
   b. tolerate a wide range of salinities.
   c. are limited to the upper end of an estuary.
   d. are limited to the lower end of an estuary.

2. Some estuarine plants accumulate large amounts of water to dilute the salts they take up. Fleshy plants such as these are known as [d]
   a. anadromous.
   b. catadromous.
   c. osmoregualtors.
   d. succulents.

3. Which type of estuarine community consists of extensive beds of oysters on the muddy bottom? [c]
   a. mangrove forests
   b. mudflats
   c. oyster reefs
   d. seagrass beds

Short Answer

4. What factors affect the behavior of water masses and circulation in estuaries? [There are many factors that affect the behavior of water masses and circulation in estuaries. The shape of the estuary and its bottom, the wind, evaporation of water from the surface, and changes in the tide all influence the distribution of salinity. Also of importance are seasonal variations in freshwater runoff from rivers as a result of rainfall patterns or snowmelt. Currents are especially important. Because most estuaries are long and narrow, the tide doesn't just rise; it rushes in, often creating strong tidal currents. In a few places the tide actually comes in as a nearly vertical wall of water known as a tidal bore. Another factor that affects circulation in estuaries is the Coriolis effect. North of the Equator, the fresh water that flows from rivers toward the sea is deflected toward the right. South of the Equator, the flow is to the left. This means that in estuaries located in the Northern Hemisphere marine organisms can penetrate farther upstream on the left side when one faces seaward. In the Southern Hemisphere they extend up the right side.]
5. What are the ecosystem services of mangroves? What conservation efforts help protect mangroves? [Mangroves provide habitat for many marine organisms. The channels that cross mangrove forests are rich nurseries for many species of commercially important shrimps, spiny lobsters, crabs, and fishes. They are also nurseries for coral reef fishes. Several species of oysters and other bivalve molluscs that live on or even within the roots of mangroves (like shipworms, Teredo) are used as food in some places around the world. Many species of land animals use mangrove forests for shelter and food. Insects feed on leaves, flowers, and the attached seedlings, while bees and bats feed on the pollen and nectar of some mangrove flowers. Birds make their homes in the branches and feed on fishes, crabs, and other prey. Snakes, frogs, lizards, bats, and other land animals also live in the mangrove trees. Mangroves contribute significant portions to the economy of many developing nations, not only in terms of fishery resources but as a source of timber, charcoal, and revenue from the tourist industry. Mangrove forests improve water quality by removing pollutants and particulate matter and help protect coasts from wave action and increasing sea levels. There is evidence that damage by the 2004 Indian Ocean tsunami would have not been as severe, if mangrove forests had not been cleared in some of these areas. Conservation efforts through protective legislation, restoration projects involving the mass replanting of mangrove seedlings, proper management, and the creation of marine protected areas and reserves have nevertheless resulted in a reduction in the rate of loss of mangrove forests in some areas. Of particular importance is the development of sustainable exploitations of fishery resources in developing countries, where economic development is often in conflict with the conservation of natural resources. Many conservation programs emphasize the education of local communities on the economic and ecological values of mangrove forests, and on providing economic alternatives to practices that lead to mangrove destruction.]

Critical thinking

6. A proposal is made to deepen the entrance and main channel of an estuary. What do you think will happen to the salt marshes that surround the channel? What do you predict will happen to the primary production of the estuary as a whole? [The deepening of the entrance and main channel of an estuary would adversely affect or simply destroy salt marshes in the vicinity. Wave action will increase and the effect of the tides that normally flow into the salt marshes is minimized. Primary production of the estuary would drop significantly.]

7. Some of the organic material manufactured in estuarine communities is exported to other ecosystems. What type of ecosystems receive this material? How is this material transported?
[The organic material that is exported is mostly in the form of fine detritus. It will be carried out of the estuary with the out−going tide and transported by currents to neighboring rocky and sandy shores, as well as to subtidal and deep−water communities.]

Data Analysis Lab
Think Critically

1. What are some differences in the fiddler crab burrows between the two locations?
At Location 1, the burrows are straight and reach a depth of up to 20 cm. At Location 2, the burrows curve as soon as they hit the oil in the sediment. They are much shallower and curved.
2. What effect do you think a shallower burrow would have on predation on fiddler crabs?
In shallow burrows, the crabs cannot hide from predators as well. Predation rates would likely increase.
3. Fiddler crabs are bioturbators who move sediments around as they dig their burrows. Why would any effects on this process be important to salt marsh communities?
When shallower burrows are made, less sediments are moved, which means less oxygen reaches the roots of the grasses. Salt mash grasses help prevent erosion and protect the shoreline. If the grasses are not as healthy or not as dense, erosion could increase.

Vocabulary Review Activity

All About Estuaries

Have students answer the following short descriptions using the vocab list from Ch. 14. All terms but two will be utilized.

- Exposed at low tide
- Most common estuary
- Forest of intertidal trees
- Excess Nutrient pollution
- Created by glaciers
- Can tolerate salinities from 5−30 ppt
- Aboveground plant roots
- Created by subsidence
- Freshwater or Saltwater marsh communities
- Export of detritus
- Created by deposits of sand
- Cordgrass
- A range of 5−20 ppt
- Underground plant stems
- Adapted to uptake large amounts of water
- Located inland from mudflats
- Can only tolerate salinities greater than 32 ppt

Answers:

- *Mudflats*
- *Drowned river valley/Coastal Plain Estuary*
- *Mangals*
- *Eutrophication*
- *Flords*
- *Euryhaline*
- *Pneumatophores*
- *Tectonic estuaries*
- *Wetlands*
- *Outwelling*
- *Bar built estuary*
- *Invasive species*
- *Brackish*
- *Rhizomes*
- *Succulents*
- *Salt Marsh*
- *Stenohaline*

Key Question Activity
Section 14.1 Origins and Types of Estuaries

Introduction
An estuary is defined as a semi−enclosed area where fresh water and seawater meet and mix. A wide variety of habitats that host many different types of organisms are included in this definition. This activity is meant to get students thinking about estuaries by discussing what they may already know about them.

Discussion
Have students discuss what they know about estuaries and why these areas are so diverse. Here are some helpful questions to help structure the discussion.

1. What physical characteristics do estuaries have and how can they vary from estuary to estuary?
2. How big are estuaries?
3. What landforms and habitats can be present in estuaries?
4. How can you tell where fresh water and seawater meet? Can you see a distinct difference between fresh water and seawater?
5. What types of organisms live in estuaries? What kind of special adaptations do you think they possess to live there?

Write the main points of the discussion on the board, or have students take turns doing so. This will help them remember these points as you go through the chapter.

Answers
The answers to these questions are not right or wrong, but rather are designed to get students thinking about the topic and encourage discussion and participation. The following answers are suggestions and are not all inclusive of what may be discussed.

1. Estuaries have a gradient in salinity, varying temperatures from the fresh and salt water, oftentimes they are shallow so they have high light penetration, may have high dissolved oxygen from mixing or low dissolved oxygen from decomposing organic matter, and high turbidity.
2. Estuaries vary in size from very small to very large. There is no one specific size of estuaries.
3. Salt marshes, bays, lagoons, inlets, sounds, fjords, harbors, or swamps
4. You can tell where freshwater and seawater meet by the salinity being somewhere between 0 (freshwater) and 32 (full strength seawater) parts per thousand. One cannot tell by looking if water is fresh or salt, it must be tested by some other method.
5. Many types of organisms live in estuaries, but there are overall less numbers of species in estuaries than there are in either freshwater or saltwater environments. Organisms in estuaries must be able to handle the extreme and constantly changing environment of the estuary, which is why not as many species are able to inhabit them. Seagrasses and seaweeds are common, as are diatoms and dinoflagellates. Many larval stages of marine species inhabit estuaries, and seabirds are also very common.

Key Question Activity
Section 14.2 Physical Characteristics of Estuaries

Introduction
The physical characteristics of an estuary, its temperature, salinity, dissolved oxygen, substrate, etc. play a very large part in what organisms can inhabit the estuary. They are also very dynamic and can change very quickly. Because estuaries are such important ecosystems that are dependent on their physical environment, scientists monitor the physical parameters in an estuary to help gauge the health of the estuary. The National Estuarine Research Reserve (NERR) is a network of 28 coastal sites that protects and studies coastal ecosystems. There is a large online database of real time data collected at the NERR sites.

Discussion
Divide the class into 5 different groups of students. Assign each group a NERR estuary. Have each group go to http://cdmo.baruch.sc.edu/get/export.cfm to get real time data on the current physical conditions of the estuary. Have each group compare and contrast the current conditions in their estuary and have them discuss how those physical conditions affect the organisms living in the estuary.

Key Question Activity
Chapter 14, Section 14.3 Estuaries as Ecosystems

Introduction
The term *estuary* is a pretty broad definition: a semi−enclosed area where fresh water and seawater meet and mix. There are several different ecosystems and habitats that can all be found within estuaries. Because of this, there are a wide variety of both environmental and economic benefits that estuaries provide.

Discussion
Divide the class into two groups. One group will discuss the economic benefits of estuaries, and the other will discuss the environmental benefit of estuaries. Give each group time to discuss the benefits of the estuaries, and assign one person to write down the benefits discussed. At the end of the discussion period have each group share what they discussed with the other group. Then, bring the entire class together to discuss how to balance protecting both the environmental and economic benefits of an estuary.

Key Question Activity
Section 14.4 Human Impact on Estuarine Communities

Introduction
Estuaries are particularly susceptible to human impacts, in large part because of their proximity to human settlements. Pollution and invasive species are two of the most damaging human impacts on estuaries. This activity will explore how toxic pollution, eutrophication, pathogens, and invasive species negatively affect estuaries.

Discussion
1. Split the class into four groups and assign one topic to each group: toxic pollution, eutrophication, pathogens, or invasive species
2. Have each group answer the following question about how their anthropogenic effect is negatively impacting estuaries. Assign one recorder for each group to write down the group's answers.
    a. What is the definition of your anthropogenic effect?
    b. How do humans cause your anthropogenic effect?
    c. How does your anthropogenic effect affect the physical environment in an estuary?
    d. What organisms are most impacted by your anthropogenic effect? (the biological affect)
    e. What can be done to decrease or fix your anthropogenic effect?
3. Once each group has time to discuss and record their answers, have each group present their findings to the class.
4. Compare and contrast the different effects in a group discussion once each of the groups has presented.

Answers
Toxic Pollution—Toxic pollution is pollution by substances that can cause serious illness or even death. Common toxins found in estuaries are pesticides, herbicides, automobile fluids like antifreeze or oil, and heavy metals like mercury or lead. Humans cause this pollution by dumping in estuaries or areas that run off to estuaries, or by using pesticides or herbicides close to an estuary. Toxins can affect the physical environment if they attach to substrates, which can poison organisms in the estuary. Biologically toxins can bioaccumulate in the food web so they have the potential to affect all organisms from the smallest plankton to the largest predators. Humans can decrease this effect by not using harmful substances in areas that drain to an estuary.

Eutrophication—Eutrophication is nutrient pollution and occurs when nutrients like nitrogen and phosphorus are introduced in excessive amounts in an environment. This causes large algal blooms that can negatively affect the estuary by causing decreased dissolved oxygen when the bloom dies and is broken down by bacteria. Humans cause this effect by using soaps with phosphates and fertilizers with nitrogen that run off directly into estuaries. Physically eutrophication causes algal blooms which cause decreased light penetration, and they can also cause blooms of algae that produce toxins that kill other animals (red tides). Biologically phytoplankton are most affected by eutrophication. Once blooms of phytoplankton die the anoxia caused by their decomposition most affected benthic organisms that cannot move to an area with higher oxygen. Humans can decrease this effect by not using excessive amounts of fertilizers containing nitrogen, and by using soaps that do not contain phosphates.

Pathogens−−Pathogens, or disease−causing organisms, include bacteria, viruses and parasites. Humans cause this anthropogenic effect when sewage enters estuaries, through ways like sewage plant leaks, livestock wastes, or sewage overflows. While pathogens don't usually have much of a physical effect on estuaries, they can be devastating biologically. The main organisms affected by pathogens are the filter

feeders like oysters and clams, but they are also a major health threat to humans who swim or fish in the estuary. Pathogens can be decreased by minimizing sewage overflows during large storm events.

Invasive species—Invasive species are plants and animals that are non−native to an area and have a potential to disrupt the ecosystem or cause harm. Humans cause this anthropogenic effect by transporting animals far outside their natural range to other ecosystems where they can potentially cause harm. This often happens in estuaries by ships that fill their ballasts in one part of the world and then empty the water in a different part of the world. Unlike other anthropogenic effects on this list, like pathogens or pollution, invasive species do not dissipate over time; they may even take over and completely disrupt the estuary. The spread of invasive species can be decreased by ships exchanging their ballast water at sea.

Chapter Project: Snapshot of an Estuary

Introduction

The National Estuarine Research Reserve (NERR) System is a network of 28 coastal locations that study and protect estuaries. The reserves represent a partnership between the National Oceanic and Atmospheric Administration and the states the individual reserves are located in. All 28 NERR sites are dedicated to research and protection, and many of the sites have real time water quality and biological monitoring data on their websites.

Task

Your task is to pick one of the 28 NERR sites and complete a snapshot of the reserve. Your snapshot should be done using Google Earth to explore your estuary and the real time data on your estuary's website found at http://www.nerrs.noaa.gov/index.html. Your snapshot should include a figure showing how the physical parameters of the estuary change from season to season and a description of the physical and biological features of your estuary. Include interesting facts about your estuary that make it unique.

Process

Use your resources to answer the following questions.

1. How does temperature affect dissolved oxygen? How can this affect estuaries?

   _____

   _____

   _____

2. What is a freshwater estuary? How can a freshwater estuary be covered under a marine reserve system?

   _____

   _____

   _____

3. What benefits do estuaries provide to human populations? What types of resources are contained within your estuarine reserve?

_____

_____

_____

Report

Once you have completed your research, use the archived data on your estuary to make a figure of how the physical conditions of the estuary change over the year. Then, write a 2−3 page report describing the physical and biological aspects of your estuary. Make sure to include the figure you generated in your report, along with a caption describing it. Include current research projects in the estuary, any resources that are being actively managed (such as fisheries) and any facts you find interesting or unique about the site.

Resources

Many online resources can be used to assist your research. These include websites, journal articles, and scientific news and magazines.

Evaluation

Read the following rubric to see how you will be scored on the Inquiry Activity.

Criteria					**Points**
	0	**5**	**10**	**15**	
Task	The tasks were not completed.	Some effort was made to complete the tasks, but the major ideas are missing.	The tasks were completed but some information was omitted or incorrect.	The tasks were completed with great attention to detail.	
Process	The process was not followed.	The process was begun but not all questions were answered.	The process was followed but some answers were incorrect.	The project showed thorough research and a deep understanding of the topic.	
Report	There was no attempt to create a report.	There was minimal effort making the report.	There was good material and ideas in the report.	The report was excellent, and showed knowledge of the topic.	
Total Score					

Chapter Project Teacher Guide and Answers

Teaching Strategies

- You may want to have a short classroom tutorial showing students how to use Google Earth.
- Make sure that at least one of the freshwater estuaries is covered by one of your students.

Resources

- The National Estuarine Research Reserve System's website needs to be used for this WebQuest http://www.nerrs.noaa.gov/index.html
- This site is a direct link to the real time and archived data from each reserve site http://cdmo.baruch.sc.edu/get/export.cfm
- Google Earth is a very useful tool that students should use to explore their estuary.

Process

1. Cold water can hold more dissolved oxygen, so warm estuarine waters are lower in oxygen and more prone to hypoxia.
2. A freshwater estuary is an area around a Great Lake that is partially enclosed where lake water meets with water from rivers or streams. While they do not contain any salt water, they are a unique mixture of two chemically distinct types of water, which is why they are covered under the marine reserve system.
3. Answers will vary but should include water filtration, marine nursery habitat, they act as buffer zones to stabilize shorelines, and they provide valuable bird habitat.

Next Generation Science Standards*

This project supports the following items in the Next Generation Science Standards:

Performance Expectation:

HS−LS2−6 Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may results in a new ecosystem.

Disciplinary Core Ideas:

LS2.C: Ecosystems Dynamics, Functioning, and Resilience

- Anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species. (HS−LS2−7)

Science and Engineering Practices:

Developing and Using Models: Modeling in 9−12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.

- Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system

Crosscutting Concepts:

Stability and Change

- Much of science deals with constructing explanations of how things change and how they remain stable. (HS−LS2−6), (HS−LS2−7)

*Next Generation Science Standard is a registered trademark of Achieve. Neither Achieve nor the lead states and partners that developed the Next Generation Science Standards was involved in the production of, and does not endorse, this product.

Hey Good Looking: Sexual Dimorphisms

An Inquiry Activity for Fiddler in the Mud

Introduction

Many organisms exhibit sexual dimorphisms, which occur when males and females of the same species are morphologically different—they look different from one another. For example, male fiddler crabs have one greatly enlarged claw and one small feeding claw, while female crabs have two small feeding claws. Sexual dimorphism can have many advantages for the survival and proliferation of a species. Perhaps it is used as an advertisement to the other sex as availability to mate (intersexual selection) or to protect a territory or group of potential mates from another individual of the same sex (intrasexual selection).

Sexual dimorphisms display in a variety of ways. Sometimes males and females will look alike except one will be much larger than the other in size. Different colorations are considered dimorphisms, as is the enlargement or ornamentation of a body part, such as the large claw in the fiddler crab.

Task

Your task is to research marine organisms (other than the fiddler crab) that exhibit sexual dimorphisms. There are many examples ranging from marine mammals to fish to invertebrates. Catalog a few species for their sexual dimorphism and note why scientists believe the adaptation evolved.

Process

Use your resources to answer the following questions.

1. Give an example of a marine species that exhibits a sexual dimorphism. How are males and females different?

_____

_____

_____

2. What advantages are there for the individual that exhibit the difference? Is this for intrasexual (between the same sex) or intersexual (between different sexes) competition?

_____

_____

_____

_____

3. Can you think of any disadvantages or trade−offs for exhibiting the dimorphism?

_____

_____

_____

Presentation

Once you have completed your research, prepare a presentation in a group of 3−4 people that chose different organisms to research. The presentation should be 5−10 minutes long and summarize different kinds of sexual dimorphisms found in the marine environment.

Resources

Many online resources can be used to assist your research. These include websites, journal articles, and scientific news and magazines.

Evaluation

Read the following rubric to see how you will be scored on the Inquiry Activity.

Criteria					**Points**
	0	**5**	**10**	**15**	
Task	The tasks were not completed.	Some effort was made to complete the tasks, but the major ideas are missing.	The tasks were completed but some information was omitted or incorrect.	The tasks were completed with great attention to detail.	
Process	The process was not followed.	The process was begun but not all questions were answered.	The process was followed but some answers were incorrect.	The project showed thorough research and a deep understand −ing of the topic.	
Presentation	There was no attempt to create a presentation.	There was minimal effort making the presentation.	There was good material and ideas in the presentation.	The presentation was excellent, and showed knowledge of the topic.	
Total Score					

Teacher Guide and Answers

Hey Good Looking: Sexual Dimorphisms

An Inquiry Activity for Fiddler in the Mud

Background Information

Teaching Strategies

- Show pictures of male and female fiddler crabs, highlighting differences in claws
- Show videos of the claw−waving rituals
- Review advantages and disadvantages of this display (attracting a mate vs attracting a predator)

Resources

- Information about sexual dimorphism in anglerfishes: http://academic.reed.edu/biology/professors/srenn/pages/teaching/web_2010/anglerfish_MFS/index.html

Process

1. Answers will vary. Common examples are elephant seals, fur seals, nudibranchs, cichlid fish, or angler fish. There are many other examples.
2. Answers will vary. For example, male elephant seals grow much larger than females. Males will fight with each other for control of a harem of females. This is an intrasexually selected adaptation and behavior.
3. One disadvantage to being the biggest male with a large harem is, actually, having a large harem. While fighting or chasing away other males, smaller males sneak into the harem to mate with females. Both males and females are documented as being "cheaters" to the system.

Ditch those Mosquito Ditches

An Inquiry Activity for Restoration of Salt Marshes

Introduction

Since the 1930s mosquito ditches have been dug in salt marshes all along the Atlantic Coast. The purpose of the ditches was to drain standing water to help control the mosquito population. As you will discover through your research, these mosquito ditches had very different effects from those that were intended.

Task

Your task is to research the effectiveness and the consequences of the digging of mosquito ditches in salt marshes along the Atlantic Coast.

Process

Use your resources to answer the following questions.

1. Why is standing water important to salt marshes?

_____

_____

_____

2. What are some of the effects of draining salt marshes?

_____

_____

_____

_____

_____

3. What is the basic mosquito life cycle? How would digging mosquito ditches help control the population?

_____

_____

_____

_____

Report

Once you have completed your research you are to create a flow chart comparing and contrasting what mosquito ditches in salt marshes are intended to do and what the possible consequences can be. Be sure to include both positive and negative outcomes of the mosquito ditches.

Resources

Many online resources can be used to assist your research. These include websites, journal articles, and scientific news and magazines.

Evaluation

Read the following rubric to see how you will be scored on the Inquiry Activity.

Criteria					**Points**
	0	**5**	**10**	**15**	
Task	The tasks were not completed.	Some effort was made to complete the tasks, but the major ideas are missing.	The tasks were completed but some information was omitted or incorrect.	The tasks were completed with great attention to detail.	
Process	The process was not followed.	The process was begun but not all questions were answered.	The process was followed but some answers were incorrect.	The project showed thorough research and a deep understanding of the topic.	
Chart	There was no attempt to create a chart.	There was minimal effort making the chart.	There was good material and ideas in the chart.	The chart was excellent, and showed knowledge of the topic.	
Total Score					

Teacher Guide and Answers

Ditch those Mosquito Ditches

An Inquiry Activity for Restoration of Salt Marshes

Background Information

Mosquito ditches were intended to reduce mosquito populations and therefore mosquito−carried diseases by draining standing water that the mosquitos use to lay their eggs. Instead, the ditches drained habitat for fish and other animals that preyed on mosquito larva, so the mosquito population often increased instead of decreased.

Resources

- Salt marsh restoration is widespread and almost any coastal state with salt marshes has several websites dedicated to their restoration.
- The University of Rhode Island has a very informative website with great information on mosquito ditches and salt marsh restoration. http://www.edc.uri.edu/restoration/html/tech_sci/restsalt.htm

Process

1. Standing water is valuable habitat for migratory birds and larval fish, and it is also important in the nitrogen and phosphorous cycling that takes place in salt marshes.
2. Answers will vary but will include loss of fish habitat, loss of a food source for fish that feed on mosquito larvae, and loss of substrate for seagrasses.
3. Adult females lay their eggs in stagnant water, and the first three stages: egg, larvae, and pupa are mainly spent under water. Adult mosquitos spend their lives above water and some species can overwinter. Mosquito ditches drain standing water, and without standing water the females cannot lay eggs so the life cycle is broken and the population decreases.