Teacher Guide—Life Science Module
Activity 1: Survival in an Estuary

Featured NERRS Estuary:
Elkhorn Slough National Estuarine Research Reserve, CA
http://nerrs.noaa.gov/Reserve.aspx?ResID=ELK

Activity Summary

In this activity, students investigate the range of conditions that selected animal and plant species need to survive in an estuary. They examine data for abiotic factors that affect life in estuaries—salinity, dissolved oxygen, temperature, and pH. Students use archived data (trend analysis graphs) and real-time conditions at the Elkhorn Slough National Estuarine Research Reserve (NERR) to predict whether a particular animal or plant species could survive in an estuary.

Learning Objectives

Students will be able to:

1. Describe three types of estuarine environments.
2. Describe the particular environmental conditions necessary for organisms to survive in an estuary.
3. List four principal abiotic factors that influence the survival of aquatic life in estuaries.
4. Determine the range of pH, temperature, salinity, and dissolved oxygen tolerated by some common estuarine species.

Grade Levels

9-12

Teaching Time

3 (55 minute) class sessions + homework

Organization of the Activity

This activity consists of 4 parts which help deepen understanding of estuarine systems:

The Estuarine Environment

Surviving Changes: Abiotic Factors that Affect Life

Surviving in an Estuary: Extreme Conditions

Optional: Investigating Other NERRS sites

Background

This activity introduces students to the nature of estuaries, estuarine environmental factors, and four important abiotic factors—pH, temperature, dissolved oxygen, and salinity—and how they vary in estuaries. The study centers on Elkhorn Slough National Estuarine Research

Reserve (NERR) in California. Elkhorn Slough is one of the relatively few coastal wetlands remaining in California. The main channel of the slough, which winds inland nearly seven miles, is flanked by a broad salt marsh second in size in California only to San Francisco Bay.

The reserve lands also include oak woodlands, grasslands and freshwater ponds that provide essential coastal habitats that support a great diversity of native organisms and migratory animals.

Review of Abiotic Factors

What follows is some basic information about four abiotic factors.

pH

pH is a measure of how acidic or basic a solution is. The pH scale ranges from 0 to 14. Solutions with a pH of less than 7 are acidic, and those with a pH greater than 7 are basic (or alkaline).

Knowledge of pH is important because most aquatic organisms are adapted to live in solutions with a pH between 5.0 and 9.0. The pH in an estuary tends to remain relatively constant because the chemical components in seawater resist large changes to pH. Biological activity, however, may significantly alter pH in the freshwater portions of the estuary.

pH is actually a measure of the amount of hydrogen ions in a solution. In fact, some people think of pH as being the "power of hydrogen." A lower pH indicates that there are more free hydrogen ions in the water, which creates acidic conditions, and a higher pH indicates there are less free hydrogen ions, which creates basic conditions. pH is equal to the negative logarithm of the hydrogen ion activity, meaning that the hydrogen ion concentration changes tenfold for each number change in pH unit. Water on the surface of Earth is usually a little acidic or basic due to both geological and biological influences.

Through a process called photosynthesis, plants remove carbon dioxide (CO_2) from the water and emit oxygen (O_2). Since CO_2 becomes carbonic acid when it dissolves in water, the removal of CO_2 results in a higher pH, and the water becomes more alkaline, or basic.

When algae naturally begin to increase in estuaries as they may do when days lengthen and the water temperature rises in spring, pH levels tend to rise. Respiration, on the other hand, releases CO_2 into the water, thus resulting in a lower pH, so pH levels may drop during the summer nights.

All aquatic organisms have a pH range to which they are adapted. Outside of this range, critical biological processes may be disrupted, leading to stress and death. Most organisms cannot live below a pH of 5 or above a pH of 9. Additionally, pH is used to monitor safe water conditions. Once the background range of pH has been established, a rise or fall in pH may indicate the release of a chemical pollutant, or an increase in acid rain. Additionally, pH affects the solubility, biological availability, and toxicity of many substances. For example, most metals are more soluble, and often more toxic, at lower pH values.

Temperature

Just knowing the temperature of the water in an estuary can give us a pretty good idea of how healthy it is. One important thing we can tell from water temperature is how much oxygen can be dissolved into the water.

Dissolved oxygen is critical for the survival of animals and plants that live in the water. As the water temperature increases, the amount of oxygen that can dissolve in the water decreases. For example, 100 % saturated fresh water at 0°C contains 14.6 mg of oxygen per liter of water, but at 20°C, it can only hold 9.2 mg of oxygen per liter. Because dissolved oxygen is critical for survival, seasonal water temperature (and dissolved oxygen) is an important indicator of habitat quality for many estuarine species.

The temperature of the water also tells us what types of plants and animals are able to live in the estuary. All plants and animals have a range of temperatures in which they thrive and reproduce. For instance, salmon will only breed at temperatures below 18°F. If the water in the estuary is outside the normal seasonal temperature range in which most estuarine organisms can comfortably live, it is probably an indication that something is adversely affecting the health of the estuary.

Differences in water temperature cause the formation of distinct, non-mixing layers in water, otherwise known as stratification, because the density of water changes with temperature. This stratification leads to chemically and biologically different regions in water.

Dissolved Oxygen

To survive, fish, crabs, oysters and other aquatic animals must have sufficient levels of dissolved oxygen (DO) in the water. The amount of dissolved oxygen in an estuary's water is the major factor that determines the type and abundance of organisms that can live there.

Oxygen enters the water through two natural processes: (1) diffusion from the atmosphere and (2) photosynthesis by aquatic plants. The mixing of surface waters by wind and waves increases the rate at which oxygen from the air can be dissolved or absorbed into the water.

DO levels are influenced by temperature and salinity. The solubility of oxygen, or its ability to dissolve in water, decreases as the water's temperature and salinity increase. Therefore, DO levels in an estuary can also vary seasonally, with the lowest levels occurring during the late summer months when temperatures are highest.

Bacteria, fungi, and other decomposer organisms can reduce DO levels in estuaries because they consume oxygen while breaking down organic matter. Oxygen depletion may occur in estuaries when many plants die and decompose, or when wastewater with large amounts of organic material enters the estuary. In some estuaries, large nutrient inputs, typically from wastewater, stimulate algal blooms. When the algae die, they begin to decompose. The process of decomposition depletes the surrounding water of oxygen and, in severe cases, leads to hypoxic (very low oxygen) conditions that can kill aquatic animals. Shallow, well-mixed estuaries are less susceptible to this phenomenon because wave action and circulation patterns supply the waters with plentiful oxygen.

Salinity and Conductivity

Under laboratory conditions, pure water contains only oxygen and hydrogen atoms, but in the real world, many substances, like salt, are dissolved in water. Salinity is the concentration of salt in water, usually measured in parts per thousand (ppt). The salinity of seawater in the open ocean is remarkably constant between 30 and 35 ppt. Salinity in an estuary varies according to one's location in the estuary, daily and storm-driven tides, and the volume of fresh water flowing into the estuary.

Salinity and conductivity are closely related. Both measure the water's ability to conduct electricity, which is a surrogate measure estimating the quantity of salts dissolved in the water. Conductivity is a more sensitive measure (parts per million or less) than salinity (parts per thousand or greater). Pure water is a very poor conductor of electrical current, but salts such as sodium, calcium, magnesium, and chloride, dissolved in the water are in ionic (charged) form and conduct electrical current. Conductivity, which is the opposite of resistance, measures the ability of water to conduct current. A higher conductivity indicates less resistance, and means that electrical current can flow more easily through the solution.

In saltwater estuaries, salinity and conductivity levels are generally highest near the mouth of a river where ocean water enters, and lowest upstream where freshwater flows in. Actual salinities vary throughout the tidal cycle, however, because as the tide rises more ocean water enters the estuary. In saltwater estuaries, salinity and conductivity typically decline in the spring when snowmelt and rain increase the freshwater flow from streams and groundwater. In freshwater estuaries, salinity or conductivity is normally the reverse. The waters of the Great Lakes have a lower salinity that the streams and rivers flowing into them. Lake water intrusion due to storm surges or seiches results in lower salinity near the mouth of the estuary. During storms and the resulting runoff, both salinity and conductivity levels usually decrease, as rainwater and the resulting surface runoff are very low in salts. Although this decrease is measurable in freshwater estuaries, it does not have the same ecological impact that it would in a marine estuary. Salinity and conductivity are frequently higher during the summer when higher temperatures increase levels of evaporation in the estuary.

Conductivity and salinity are dependent on many factors, including geology, precipitation, surface runoff, and evaporation. Conductivity, because it is a much more sensitive measurement, is also very temperature dependent. It increases as water temperature increases because water becomes less viscous and ions can move more easily at higher temperatures. Because of this, most reports of conductivity reference specific conductivity. Specific conductivity adjusts the conductivity reading to what it would be if the water were 25°C. This is important for comparing conductivities from waters with different temperatures.

Environmental factors that increase conductivity and salinity include: increased temperature, fertilizers from agriculture, sewage, road runoff containing automobile fluids and de-icing salts, and a local geology high in soluble minerals, such as carbonates. Conductivity and salinity also increase due to evaporation. The Great Salt Lake in Utah is an extreme example of how evaporation can increase salinity. On warm days, the evaporation of water concentrates the ions that remain behind, resulting in water with higher conductivity and salinity. Often, small diurnal fluctuations in conductivity and salinity are seen as a result of evaporation during the day and condensation and groundwater recharge at night. In saltwater estuaries, the influx of ocean water due to rising tides increases salinity and conductivity within the estuary.

Estuarine organisms have different tolerances and responses to salinity changes. Many bottom-dwelling animals, like oysters and crabs, can tolerate some change in salinity, but salinities outside an acceptable range will negatively affect their growth and reproduction, and ultimately, their survival.

Salinity also affects chemical conditions within the estuary, particularly levels of dissolved oxygen in the water. The amount of oxygen that can dissolve in water, or solubility, decreases as salinity increases. The solubility of oxygen in seawater is about 20 percent less than it is in fresh water at the same temperature.

- Adapted from the NOAA/NOS Estuary Discovery Kit.. URL:http://oceanservice.noaa.gov/education/kits/estuaries/estuaries10_monitoring.html. Accessed: 2008-07-20.
(Archived by WebCite® at http://www.webcitation.org/5ZSbp3lvp)

Materials

Students

- ❑ Need to work in a computer lab or with a computer and projector
- ❑ Copy of the *Student Reading 1 Introduction to South Marsh*
- ❑ Copy of the *Student Reading 2 Survival in an Estuary*
- ❑ *Copy of Student Worksheet Survival in an Estuary*
- ❑ Copy of *Data* Sheet South Marsh at Elkhorn Slough 2004-05
- ❑ View the SWMP tutorial http://coast.noaa.gov/swmp/tutorial/tutorial.html

Teachers

- ❑ Download the PowerPoint presentation entitled *Survival in an Estuary. (*To find the presentation go to the Estuaries.noaa.gov website, choose the Curriculum tab, click on the sub-tab titled High-School Curriculum, Life Science and find the presentation under “Supporting Materials”.)
- ❑ Old Woman Creek SWMP tutorial. (To find the tutorial go to the Estuaries.noaa.gov Web site, choose the Curriculum tab, click on Tutorials, and then find the “Learn About the SWMP Data”)
- ❑ Bookmark the site: <http://estuaries.noaa.gov/ScienceData/Graphing.aspx>.

Equipment:

- ❑ Computer lab or
- ❑ Computer and Projector

National Science Education Standards

Content Standard A: Science as Inquiry

A3. Use technology and mathematics to improve investigations and communications.

A4. Formulate and revise scientific explanations using logic and evidence.

A6. Communicate and defend a scientific argument.

Content Standard C: Life Science

C4. The interdependence of organisms
C5. Matter, energy, and organization in living systems
C6. The behavior of organisms

Content Standard E: Science and Technology

E2. Apply and adapt a variety of appropriate strategies to solve problems

Preparation

- Download the PowerPoint presentation entitled *Survival in an Estuary*, and prepare to project it in front of the class.
- Review the Old Woman Creek SWMP tutorial (on the Estuaries.noaa.gov Web site. This is a large file, please be patient downloading it). Students will be shown sections of the tutorial to visually explain abiotic parameters to students.
- If possible, arrange for students to have access to online data either by obtaining a computer projector to present the data in front of the whole class or by arranging for student groups to view the data on individual computers. On the computer(s), bookmark the site: <http://estuaries.noaa.gov/ScienceData/Graphing.aspx>. Static data are also provided in this guide if arranging computer access is difficult.
- Make copies of the *Student Reading*, *Student Worksheet*, and *Student Data Sheet*. The graphs on the *Student Data Sheet* can alternatively be projected in front of the class.

Procedure

Part 1 — The Estuarine Environment

1a. Ask the students what resources and conditions they need to survive in their environment. They will probably mention food, water, warm clothes, etc. They may forget things like oxygen to breathe, and the right array of vitamins and minerals, amino acids, and other chemical compounds needed to maintain good health. Choose an estuarine animal or plant and ask students to suggest factors such as temperature that affect conditions in its habitat. List them on the board. Bring up the water quality factors used in this activity if students do not include them:

- temperature
- pH
- salinity
- dissolved oxygen.

For your information, the student worksheet contains a list of specific conditions necessary for survival for selected species.

1b. Show students the Old Woman Creek SWMP tutorial sections that deal with SWMP data and water quality factors.

2. Show the PowerPoint *Survival in an Estuary* and ask students to describe the environment they see. Ask some probing questions as they view the slides:
   - What are the water conditions like—deep or shallow, wide or narrow, salty or fresh?
   - What is the biological community like—rich and abundant, sparse, or in between?
   - Have students read the introductory section of their handout.

3. Have students complete Part 1 of the *Student Worksheet—Survival in an Estuary*.

4. Have students read the *Student Reading—Survival in an Estuary* and *Student Reading—Introduction to South Marsh.*

Part 2 — Survival Changes: Abiotic Factors that Affect Life

5. Go over the graphs on the *Student Data Sheet—South Marsh at Elkhorn Slough 2004-5*, discussing the units on the axes: the y-axis of each graph is different; the x-axis of each graph represents one year of time at South Marsh in the Elkhorn Slough.

6. Have students complete Part 2 of the *Student Worksheet—Survival in an Estuary.*

7. Review and discuss the Part 2 tasks and questions.

Part 3 — Surviving in an Estuary: Extreme Conditions

8. Use the following procedure to have students access or display in front of the class the graphs that show the actual values, measured by buoy, of the four factors: water temperature, pH, salinity, and dissolved oxygen.
   - Go to <http://estuaries.noaa.gov/ScienceData/Graphing.aspx> to find the graphing tool and click on the tutorial to learn how to generate a graph.
   - Choose the type of data: water for water quality parameters and then click on "CA, Elkhorn Slough, South Marsh"

Teacher Notes:

- To find whether a station will have today's data we recommend checking this link first: http://www.estuaries.gov/ScienceData/Data.aspx
- If you cannot access today's gauge data, use data for 10/4/07. You will need to choose, at minimum, one day's worth of data. You may want to increase the amount of data that students analyze and compare by adding several more days, months or years' worth of data.

Timestamp: 10/04/2007 06:15	Salinity: 31.3 ppt
Water Temp: 17.1 C	Dissolved Oxygen: 5.3 mg/l
Percent Saturation: 66.8 %	Depth: 1.72 meters
Turbidity: 5 NTU	pH: 8.2 units the student handouts section.
Specific Conductivity: 47.98	

   - Project the buoy data on the screen and assist students in interpreting the readings.

9. Have students complete Part 3 of the *Student Worksheet—Survival in an Estuary.*

Check for Understanding

1. Direct your students to the Data Graphing Tool on estuaries.noaa.gov: <http://estuaries.noaa.gov/ScienceData/Graphing.aspx>. Help students navigate through the site until they can successfully download trend analysis data for 2005 from one monitoring station at four other NERR sites. Encourage them to choose sites both in your region and in other parts of U.S. coastal areas. OR, download sample data from four sites and hand them out to students.
2. Direct students to fill out an *Extreme Conditions* table for each site.
3. Have students create graphs comparing parameter ranges and time between extremes for new sites with South Marsh data.
4. Discuss with students the patterns they see and ask them to explain why the ranges and rates of change for each factor vary at different estuary sites. Or ask them to write their answers down and collect student work to serve as a summative evaluation for this activity.

Optional Extension Inquiries

- Locate a local water source (pond, river, stream, or lake) close to your school.
- Have students monitor water temperature, pH, salinity, and DO (if possible) daily or weekly over an extended period of time.
- Direct students to graph their summary data and then compare their data to the variation of parameters in the NERR sites featured in this activity.
- Discuss with students the differences in water quality between your local site and that of the NERR sites. Is your local water source habitable for all animal species featured in this activity? What could be done to improve the water quality in your local water source?

Teacher Worksheet with Answers
Activity 1: Survival in an Estuary

1a. Why is it important to monitor abiotic factors in estuarine environments?

Answer: It is important to monitor parameters such as pH, temperature, salinity, and DO because each of these factors must remain within a certain range to ensure the survival of species living in the estuary. Each of these parameters can exceed their normal range when either natural (storms, floods) or human-caused events (runoff from farms, factories, power plants, sewage treatment facilities) occur.

1b. Based on your observations of the images, describe the environment of species living in an estuary. Consider factors such as temperature, water flow, salinity, and weather to name a few.

Answer: Estuaries are complex environments in which diverse species exist or vanish depending on physical and chemical factors. The environment of South Marsh is governed by large swings of temperature and other factors due to seasonal changes. Student answers about their organism will vary.

1c. How is surviving in an estuary different than surviving in a forest, a desert, or in the open ocean?

Answer: Surviving in an estuary is difficult. In an estuary, environmental factors can change rapidly. Conditions in estuaries vary more than in many other types of habitats. Dramatic changes in pH, salinity, and temperature occur frequently and regularly in estuaries. In deserts or the open ocean, conditions are more stable and changes usually take place more slowly.

2. Choose one animal that was highlighted in the images of Part 1. What strategies and adaptations do you think your chosen aquatic species uses to cope with changing abiotic conditions in South Marsh?

Answer: Answers will vary. Hibernation might be mentioned as a strategy to cope with cold, wintry conditions. Some plants such as cordgrass have special filters in their root system that removes salt from the water it absorbs in from the saltmarsh. Bivalves like mussels, clams, and oysters close their shells during low tide and stop feeding and change their method of respiration until they are again covered with seawater. Some aquatic species can migrate to areas with more favorable conditions and move up river or down depending on the salinity at a particular time.

3a. After examining the range of tolerance information for five estuarine species, which of the five organisms do you think would thrive in the abiotic conditions of South Marsh today? Which could survive over the course of a year?

Answer: Answers will vary depending on the current abiotic data.

3b. Review the two-year data set for each abiotic factor in this activity. Choose whether each of the five species on your list is:

i) likely to survive and live in South Marsh

ii) might do fairly well

iii) doubtful to survive given the long-term environmental conditions of South Marsh.

Explain your reasoning for each species.

Answer:

oysters = Salinity of the water is uniformly too high for oysters.

clams = Water temperatures are too cold for clams to spawn.

alewife = DO levels are on the low side.

blue crab = Yes, all factors are within the survival limits of a blue crab.

cohoe salmon = DO somewhat low for salmon, average temperature is too high even though the salinity is good.

Student Reading—1
Activity 1: Introduction to South Marsh

South Marsh is part of the Elkhorn Slough National Estuarine Research Reserve in California. The South Marsh Complex is located on the southeastern side of Elkhorn Slough. The entire complex is approximately 415 acres in size. Mudflat areas with some subtidal creeks, fringing tidal marsh, and created tidal marsh islands dominate the main areas.

Elkhorn Slough is one of the relatively few coastal wetlands remaining in California. The main channel of the slough, which winds inland nearly seven miles, is flanked by a broad salt marsh second in size in California only to San Francisco Bay.

The reserve lands also include oak woodlands, grasslands and freshwater ponds that provide essential coastal habitats that support a great diversity of native organisms and migratory animals.

Figure 1. Satellite view of Elkhorn Slough NERR

More than 400 species of invertebrates, 80 species of fish, and 200 species of birds have been identified in Elkhorn Slough. The channels and tidal creeks of the slough are nurseries for many species of fish.

At least six threatened or endangered species utilize the slough or its surrounding uplands, including peregrine falcons, Santa Cruz long-toed salamanders, California red-legged frogs, brown pelicans, least terns, and sea otters.

Additionally, the slough is on the Pacific Flyway, providing an important feeding and resting ground for many types of migrating waterfowl and shorebirds. The slough and surrounding habitat are renowned for their outstanding birding opportunities.

Many habitat types are located within a short distance from the slough. Upland hills with oak, pine, eucalyptus, grassland and maritime chaparral surround the slough. Several thousand acres of salt marsh, tidal flats and open water comprise the main channel of the slough. Beach and sand dunes separate the estuary from Monterey bay. Riparian habitat is also found on the reserve. Agricultural lands and residential areas border the reserve. The close proximity of these varied habitats supports a remarkable diversity of plant and animal species in a relatively small area.

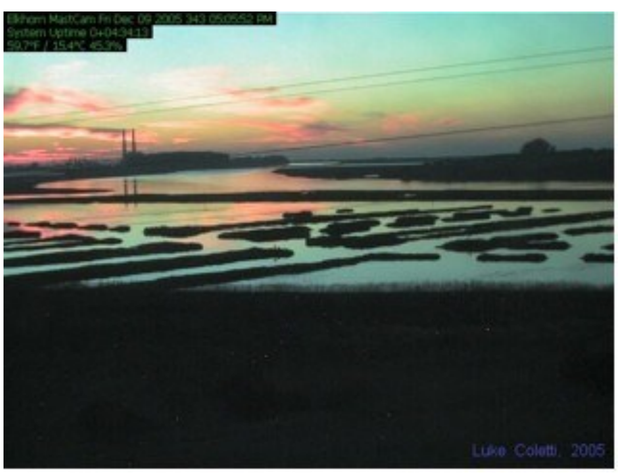

Figure 2. South Marsh is in the foreground of this image.

Figure 3. The Elkhorn Slough National Estuarine Research Reserve encompasses only 1400 acres of marsh and upland habitat in the top right corner of this image. The rest of Elkhorn Slough and the surrounding lands are owned and managed by a variety of other individuals and entities including the California Department of Fish and Game, The Nature Conservancy, the Elkhorn Slough Foundation, the Moss Landing Harbor District, and the Monterey Bay National Marine Sanctuary

— Adapted from http://nerrs.noaa.gov/ElkhornSlough/welcome.html

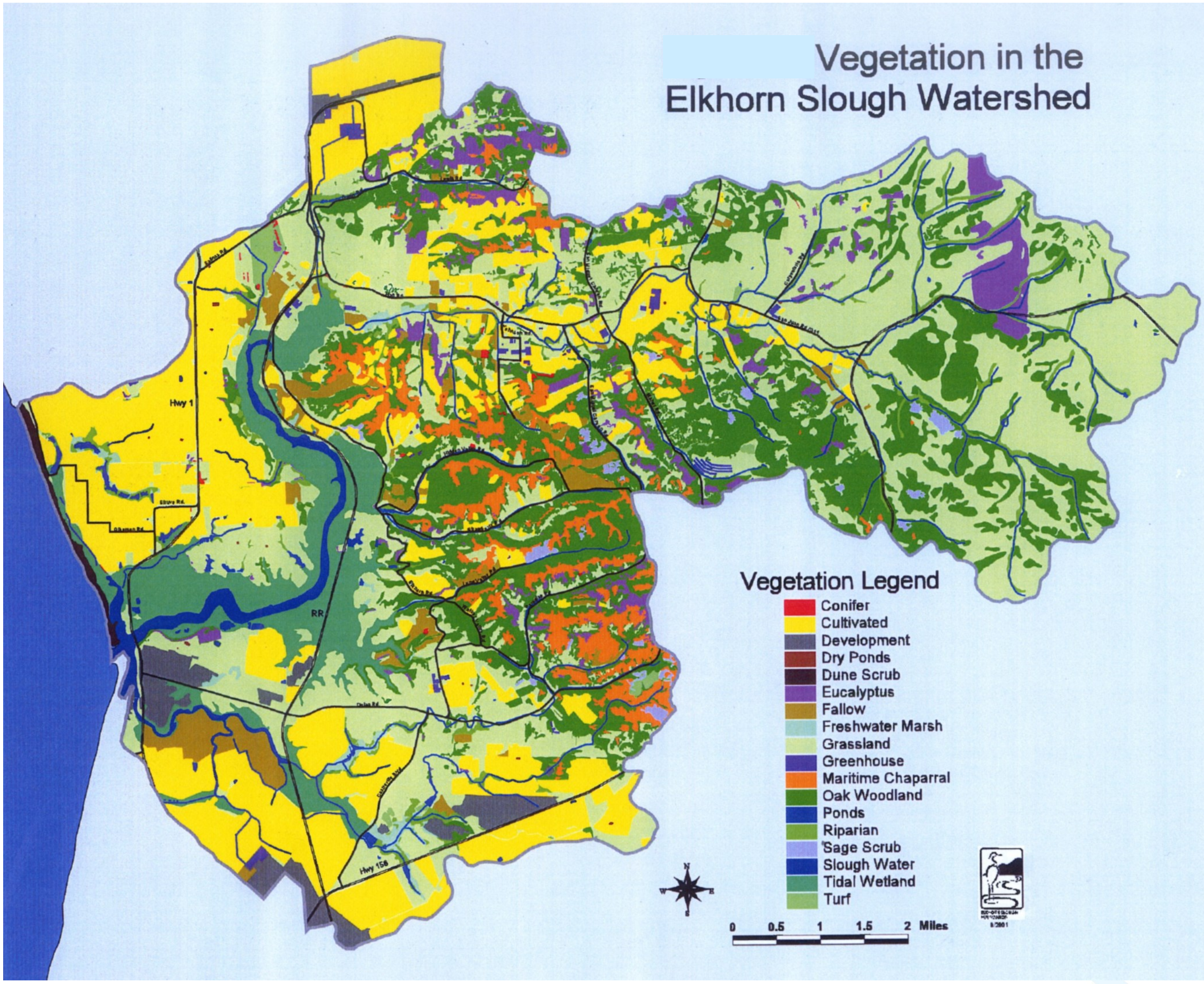

Figure 4. Vegetation map of the Elkhorn Slough watershed courtesy of the Elkhorn Slough Foundation.

Student Reading—2
Activity 1: Survival in an Estuary

An **estuary** is a partially enclosed body of water where two different bodies of water meet and mix such as fresh water from rivers or streams and salt water from the ocean, or fresh water from rivers or streams and chemically distinct water of the Great Lakes. In estuaries, water levels are affected by lunar or storm driven tides. In fresh water, the concentration of salts, or salinity, is nearly zero. The salinity of water in the ocean averages about 35 parts per thousand (ppt). The mixture of sea water and fresh water in estuaries is called **brackish water**.

Estuaries are transitional areas that connect the land and the sea, as well as freshwater and saltwater habitats. The daily tides (the regular rise and fall of the sea's surface) are a major influence on many of these dynamic environments. Most areas of the Earth experience two high and two low tides each day. Some areas, like the Gulf of Mexico, have only one high and one low tide each day. The tidal pattern in an estuary depends on its geographic location, the shape of the coastline and ocean floor, the depth of the water, local winds, and any restrictions to water flow. For example, tides at the end of a long, narrow inlet might be heightened because a large volume of water is being forced into a very small space. However, the tidal change in wetlands composed of broad mud flats might appear to be rather small.

While strongly affected by tides and tidal cycles, many estuaries are protected from the full force of ocean waves, winds, and storms by reefs, **barrier islands**, or fingers of land, mud, or sand that surround them. The characteristics of each estuary depend upon the local climate, freshwater input, tidal patterns, and currents. Truly, no two estuaries are the same.

Survival for any species, regardless of its environment, depends on the ability to adapt to changing conditions. Humans can go inside to get warm on a freezing cold day or put on a heavy coat and gloves. Or if the water main breaks or if the well runs dry, we can hop in our cars and obtain water from another source like a neighbor or local store. For plants and animals that live in an aquatic environment, adaptation is sometimes much more difficult. And for every species that spends most of its time in water, sudden changes in the environment, whether caused by natural agents (storms) or human intervention (pollutants), can spell disaster and lead to the death of many members of the aquatic community.

In estuaries, all plant and animal species live in a transition zone where fresh and salt water meet. Factors that cause change in estuarine environment fall into two categories: **abiotic** and **biotic**. Abiotic factors are those that occur in physical environment such as amount of sunlight, climate, and the geology of the area. Biotic factors are those that deal with the organism and other organisms they share their environment with, including their interaction, wastes, disease and predation.

To measure changes in the physical environment, biologists use factors that relate to natural processes or human actions. These include:

pH

Scientists use pH as an indicator of whether water is acidic or basic. pH is measured on a scale of 1 to 14, where numbers less than 7 are increasingly acidic and numbers greater than 7 are increasingly basic. Distilled water has a pH of 7 and is said to be neutral. Water on the surface of Earth is usually a little acidic or basic due to both geological and biological influences.

pH is actually a measure of the amount of hydrogen ions in solution. In fact, some people think of pH as being the "power

Figure 5. Barrier beach closed

Figure 6. Barrier beach open

of hydrogen." A lower pH indicates that there are more free hydrogen ions in the water, which creates acidic conditions, and a higher pH indicates there are less free hydrogen ions, which creates basic conditions. pH is equal to the negative logarithm of the hydrogen ion activity, meaning that the hydrogen ion concentration changes tenfold for each number change in pH unit. Water on the surface of Earth is usually a little acidic or basic due to both geological and biological influences.

All aquatic organisms have a pH range to which they are adapted. Outside of this range, critical biological processes may be disrupted, leading to stress and death. Most organisms cannot live below a pH of 5 or above a pH of 9. Additionally, pH is used to monitor safe water conditions. Once the background range of pH has been established, a rise or fall in pH may indicate the release of a chemical pollutant or an increase in acid rain. Additionally, pH affects the solubility, biological availability, and toxicity of many substances. For example, most metals are more soluble, and often more toxic, at lower pH values.

Temperature

Temperature is a measure of kinetic energy, or energy of motion. Increasing water temperature indicates increasing energy, or motion of water molecules and substances dissolved in the water. Temperature is a critical factor for survival in any environment. Organisms that live in water are particularly sensitive to sudden changes in temperature.

The Celsius temperature scale is used worldwide to measure temperature. Temperature has a significant impact on water density. Water density is greatest at 4 degrees Celsius, meaning that water at higher or lower temperatures will float on top of water at or near 4º C. This is why ice floats on water, and warm water floats over cooler water. Differences in water temperature cause the formation of distinct, non-mixing layers in water, otherwise known as stratification. This stratification leads to chemically and biologically different regions in water.

Salinity and Conductivity

Salinity and conductivity are measures of the dissolved salts in water. Salinity is usually described using units of parts per thousand or ppt. A salinity of 20 ppt means that there are 20 grams of salt in each 1000 grams of water. Because it is impractical to routinely determine the total amount of salts dissolved in water, a surrogate measure—the ability of the water to conduct electricity—is made for determining both conductivity and salinity. All aquatic life in an estuary must be able to survive changes in salinity. All plants and animals have a range of salinity to which they are adapted. Outside of this range, they will be unable to function and may die.

Salinity and conductivity are closely related. Conductivity and salinity are measures of what is dissolved in the water. Pure water is a very poor conductor of electrical current, but salts dissolved in the water are in ionic (charged form) and conduct electrical current. Conductivity, which is the opposite of resistance, measures the ability of water to conduct current. A higher conductivity indicates less resistance, and means that electrical current can flow more easily through the solution. Because dissolved salts conduct current, conductivity increases as salinity increases. Common salts in water that conduct electrical current include sodium, chloride, calcium, and magnesium.

Salinity affects the ability of water to hold oxygen, and seawater holds approximately 20% less oxygen than freshwater. Many chemical reactions that determine the concentration of nutrients and metals in the water are influenced by salinity. The conductivity and salinity of seawater is very high while these parameters are comparatively low in tributaries and rivers. Freshwater lakes typically have conductivities and salinities even lower than those of inland streams. This is because inland streams pick up salts from rocks, soils, and roads as they flow over the landscape.

Many chemical reactions that determine the concentration of nutrients and metals in the water are influenced by salinity. For instance, salinity and conductivity affect the ability of particles to flocculate, or stick together, which is important in determining turbidity levels and sedimentation rates. Salinity also increases the density of water, with seawater being heavier than freshwater. This density difference inhibits mixing. In fact, conductivity and salinity serve as excellent indicators of mixing between inland water and sea or lake water, and they are particularly useful in indicating pollution events or trends in freshwater. For example, an overdose of fertilizers or the application of road salt will cause spikes in conductivity and salinity.

Conductivity and salinity are dependent on many factors, including geology, precipitation, surface runoff, and evaporation. Since conductivity is a much more sensitive measurement than salinity, it is more impacted by changes in temperature. Conductivity increases as water temperature increases because water becomes less viscous and ions can move more easily at higher temperatures. Because of this, most reports of conductivity reference specific conductivity. Specific conductivity adjusts the conductivity reading to what it would be if the water was 25°C. This is important for comparing conductivities from waters with different temperatures.

Dissolved Oxygen

Dissolved oxygen (DO) is the amount of oxygen gas that is dissolved in a sample of water. DO is usually measured in units of milligrams per liter (mg/L). Just as we need air to breathe, aquatic plants and animals need dissolved oxygen to live. Dissolved oxygen is used for respiration, which is the process by which organisms gain energy by breaking down carbon compounds, such as sugars. Dissolved oxygen is also essential for decomposition, which is a type of respiration in which bacteria break down organic materials for energy. Decomposition is an important process that recycles nutrients and removes organic materials such as dead vegetation from our waterways. Because dissolved oxygen is required for aquatic life, balancing the sources and sinks of dissolved oxygen is essential in maintaining a healthy ecosystem.

The concentration of dissolved oxygen in water is dependent on a number of interrelated factors, including biological factors, such as the rates of photosynthesis and respiration, and physical and chemical factors, such as temperature, salinity, and air pressure.

Dissolved oxygen enters the water by diffusion from the air and as a byproduct of photosynthesis. Diffusion from the air occurs very quickly in turbulent, shallow water or under windy conditions. The amount of oxygen that can dissolve in water is dependent on water temperature, salinity, and air pressure. As temperature and salinity increase, and pressure decreases, the amount of oxygen that can be dissolved in water decreases. Cold water holds more dissolved oxygen than warm water, and water at sea level holds more dissolved oxygen than water at high altitudes. Seawater holds approximately 20% less oxygen than freshwater at the same temperature and altitude.

— Adapted from NOAA's National Ocean Service Estuaries Discovery Kit

Student Worksheet
Activity 1: Survival in an Estuary

Student Name:____

Procedure

Part 1 — The Estuarine Environment

You will be shown a number of images of estuaries. If you were a (specific) animal or plant living in an (specific location) estuary, what factors seen in these images might influence whether you survive or not? Take notes as the images are shown and then answer the following questions.

1a. Why is it important to monitor abiotic factors in estuarine environments?

1b. Based on your observations of the images, describe the environment of species living in an estuary. Consider factors such as temperature, water flow, salinity, and weather to name a few.

1c. How is surviving in an estuary different than surviving in a forest, a desert, or in the open ocean?

Part 2 — Surviving Changes: Abiotic Factors that Affect Life

You will investigate two years' worth of graphical data that describe four abiotic factors affecting the survival of aquatic species at South Marsh in the Elkhorn Slough.

For each graph on the *Student Data Sheet—South Marsh at Elkhorn Slough 2004-5*, determine the lowest and highest value of each abiotic factor. Then determine the approximate time (in days) that elapsed between these two measurements.

Extreme Conditions at South Marsh Table

	2004			2005		
Factor	**High**	**Low**	**Time Between**	**High**	**Low**	**Time Between**
temperature						
pH						
salinity						
dissolved oxygen						

Next, find the range for each factor (high value - low value) for 2004 and 2005.

2. Choose one animal that was highlighted in the images in Part 1. What strategies and adaptations do you think your chosen aquatic species uses to cope with changing abiotic conditions in South Marsh?

Part 3 — Surviving in an Estuary: Extreme Conditions

You will explore the actual values for each abiotic factor on a specific day. Your teacher will project the buoy readings for today's date or supply a hardcopy sheet with data for another day.

Record the date your data was gathered.

date ____

Record the values for temperature, salinity, dissolved oxygen, and pH.

temperature ____

pH ____

salinity ____

dissolved oxygen ____

Consult the list of *Limits of Tolerance to Environmental Factors for Selected Organisms* for the animals, and answer the following questions.

3a. After examining the range of tolerance information for five estuarine species, which of the five organisms do you think would thrive in the abiotic conditions of South Marsh today?

3b. Review the two-year data set for each abiotic factor in this activity. Choose whether each of the five species on your list is:

i) likely to survive and live in South Marsh

ii) might do fairly well

iii) doubtful to survive given the long term environmental conditions of South Marsh.

Explain your reasoning for each species.

Limits of Tolerance to Environmental Factors for Selected Organisms

Oysters

- Grow best in water with a salinity of 12 ppt and above, perish if salinity is below 5 ppt or above 25 ppt
- Spawn only when the water temperature hits 18°C for four hours
- Spawn much more prevalent when salinity is over 20 ppt
- Need a DO level of around 4 mg/l
- Best growth when pH is between 7.5 and 8.5

Clams

- Grow best when the water salinity is above 15 ppt
- Spawn only when the water temperature hits 24°C for four hours
- Clam eggs die when the salinity is below 20 ppt
- Need a DO level of around 4 mg/l
- Optimal growth occurs between 10 and 25°C

Alewife

- Adult and juvenile fish need a DO level of at least 3.6 mg/l
- Alewife eggs and larvae need a DO level of 5 mg/l or more
- Must have a pH higher than 5 but less than 9

Blue Crab

- Needs a DO level of 3 mg/l or more for survival, optimal at 5 mg/l
- Thrives if pH is between 6.8 and 8.2

Coho Salmon

- Like a DO level of 6 mg/l or higher
- Require a salinity of greater than 15 ppt
- Prefer temperatures between 4° and 20°C, do best at 13°C
- Spawn only when temperature is 18°C or higher
- Newly hatched salmon need a DO level of at least 5 mg/l to survive
- pH of 4.0 or lower or higher than 9 is lethal for salmon

Student Data Sheet
Activity 1: South Marsh at Elkhorn Slough 2004

Salinity

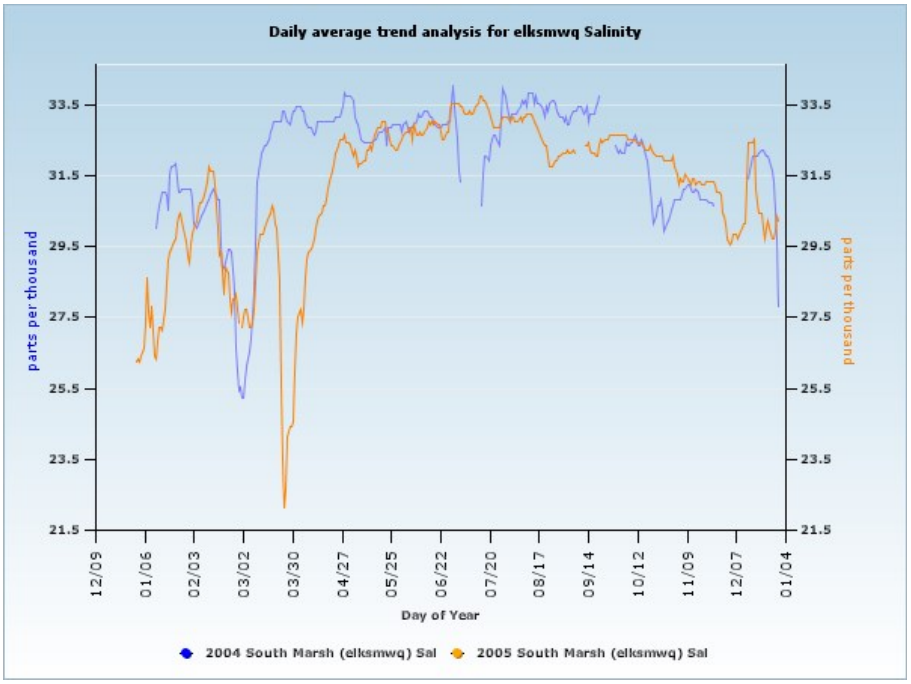

Figure 7.
Salinity: South Marsh

Dissolved Oxygen

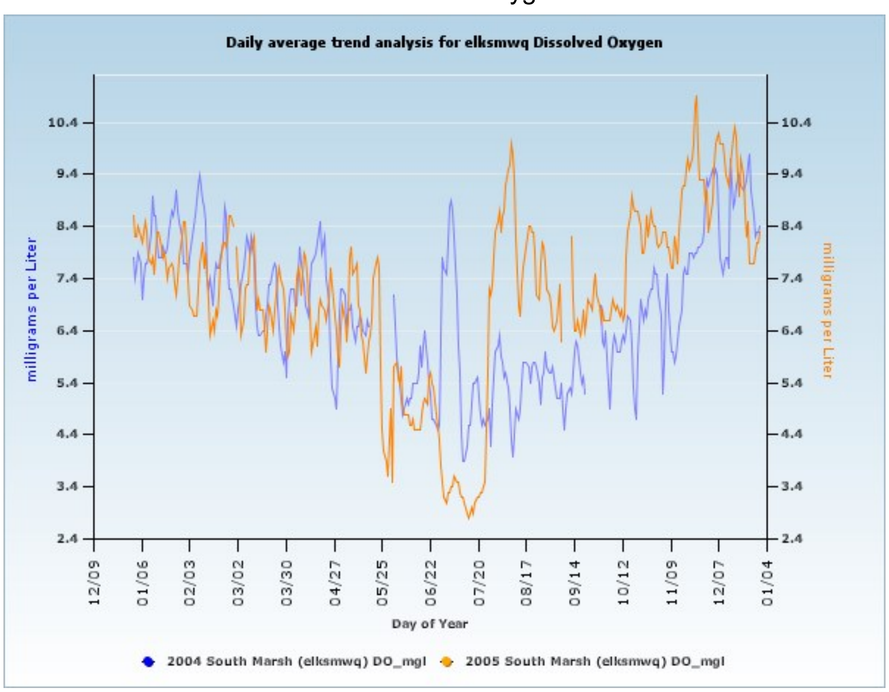

Figure 8.
DO: South Marsh

Water Temperature

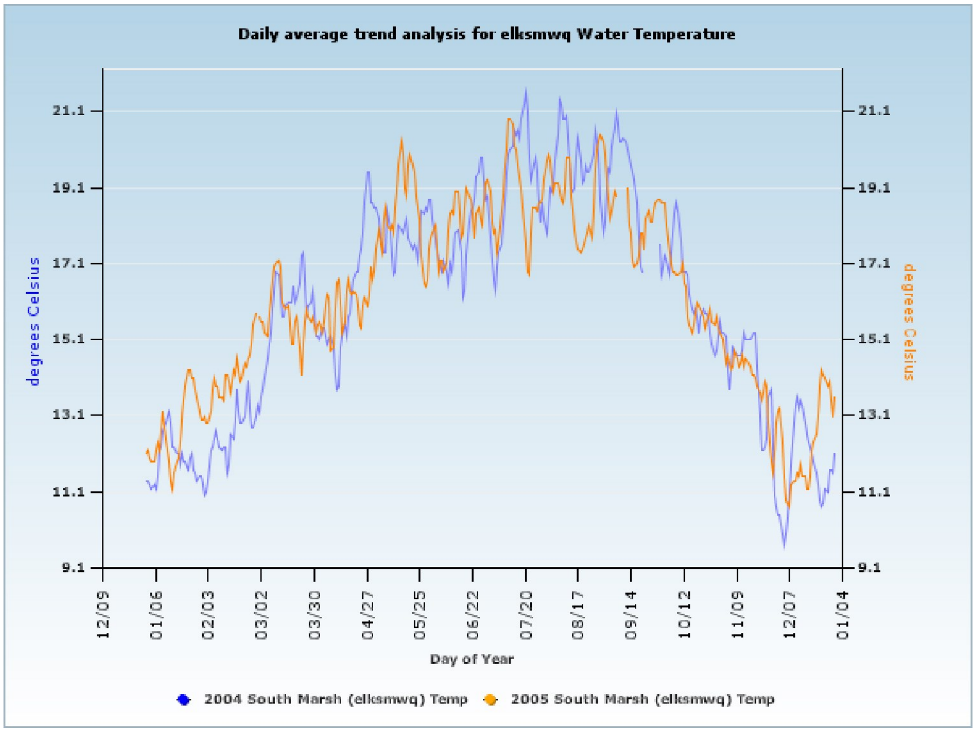

Figure 9.

Water temperature: South Marsh

pH

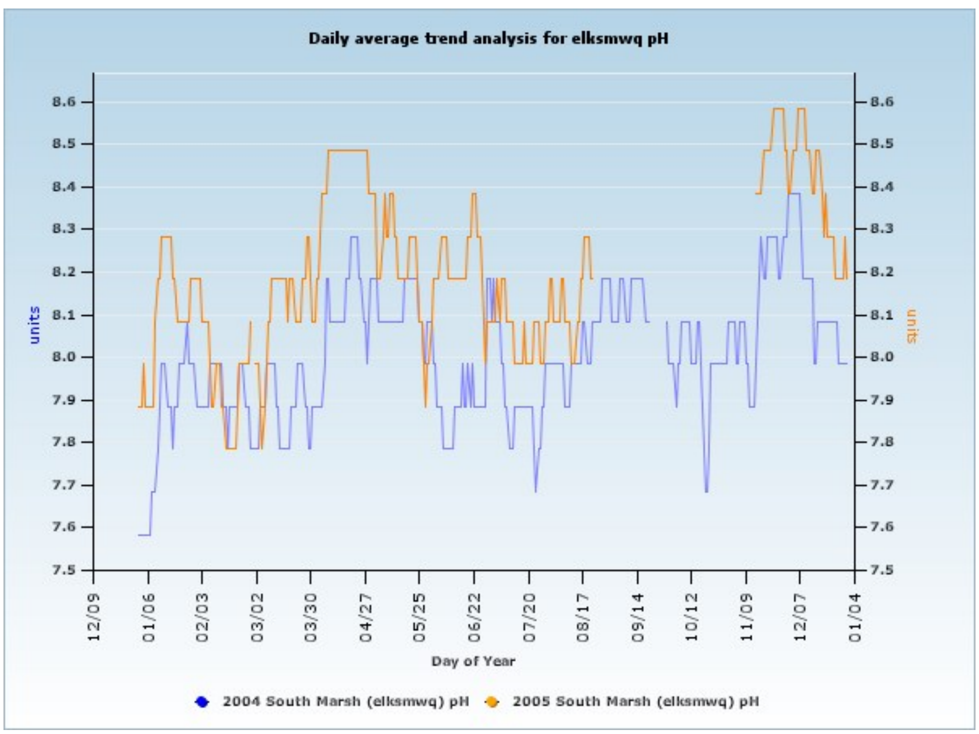

Figure 10.

pH: South Marsh