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

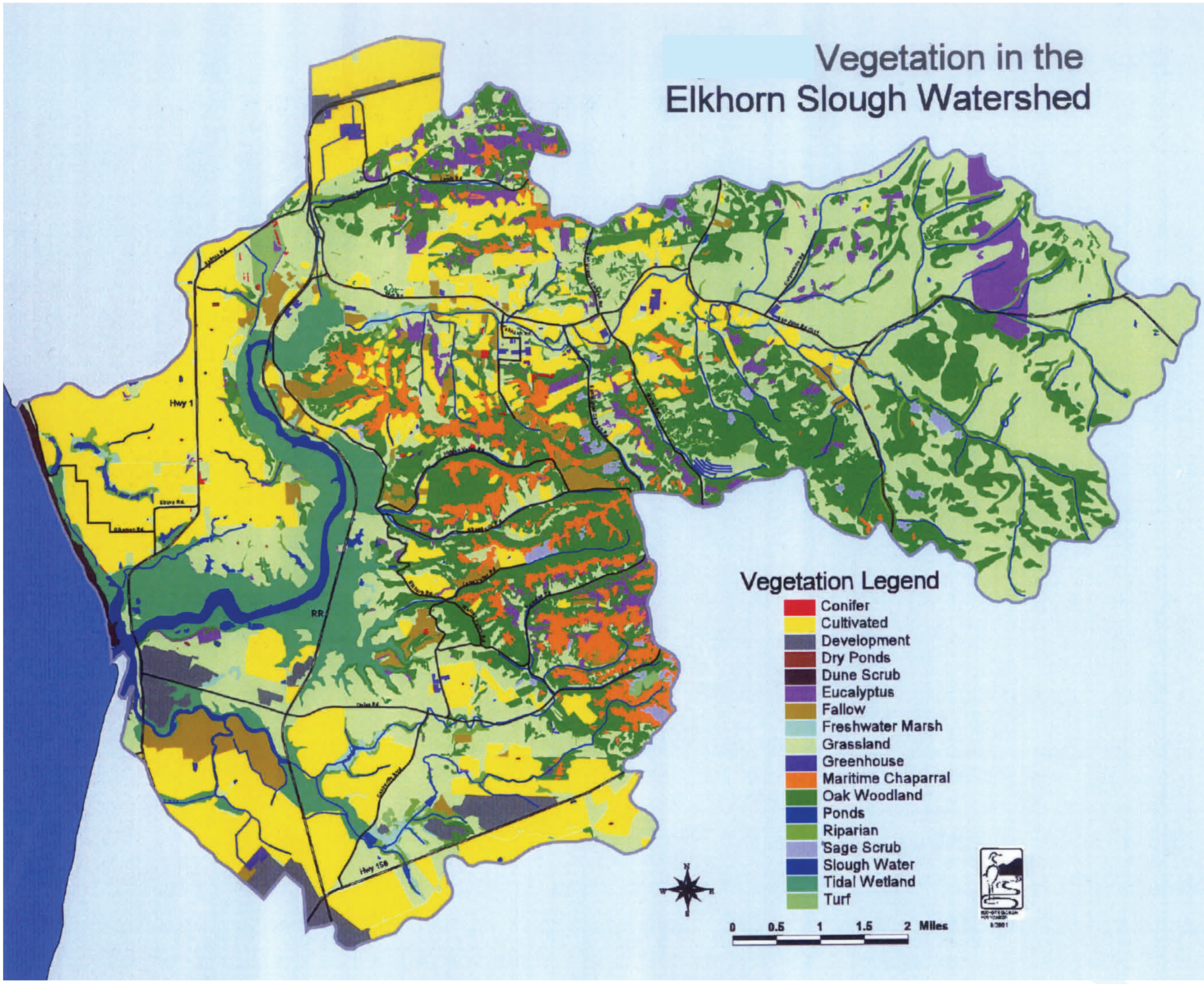

Figure 4. Vegetation map of the Elkhorn Slough watershed courtesy of the Elkhorn Slough Foundation.

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

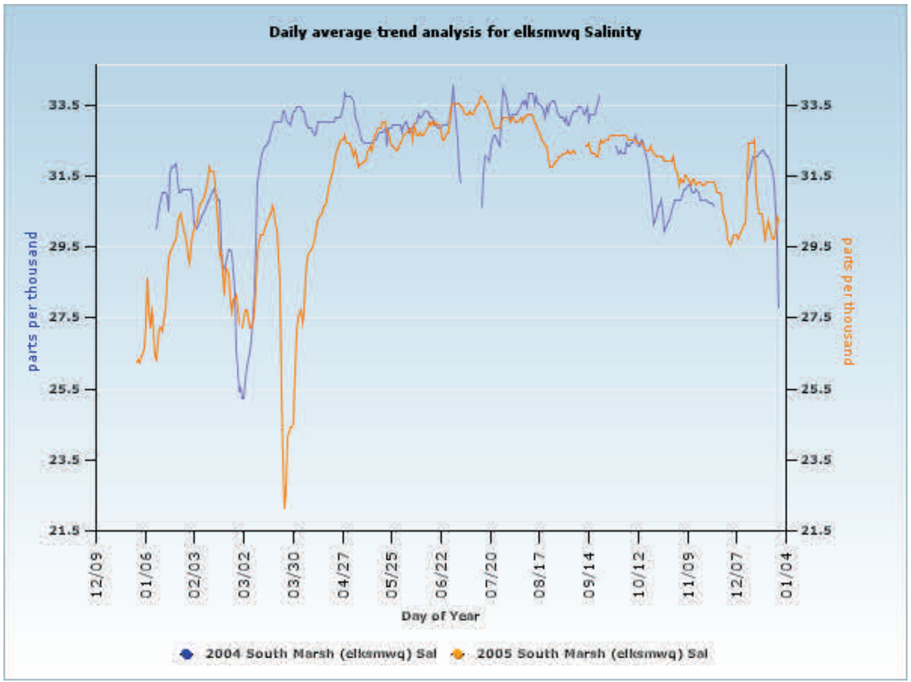

Figure 7.
Salinity: South Marsh

Dissolved Oxygen

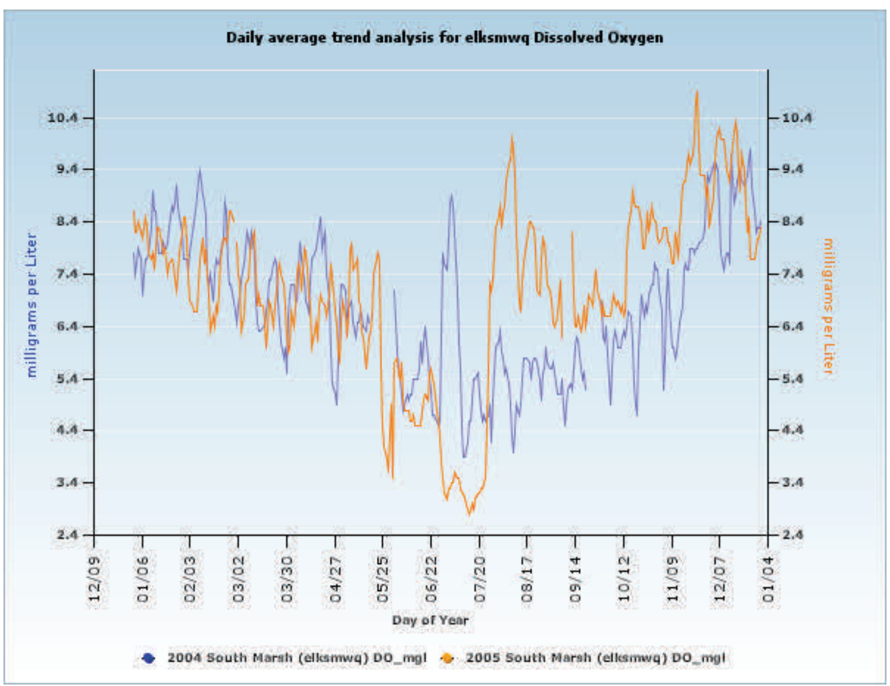

Figure 8.
DO: South Marsh

Water Temperature

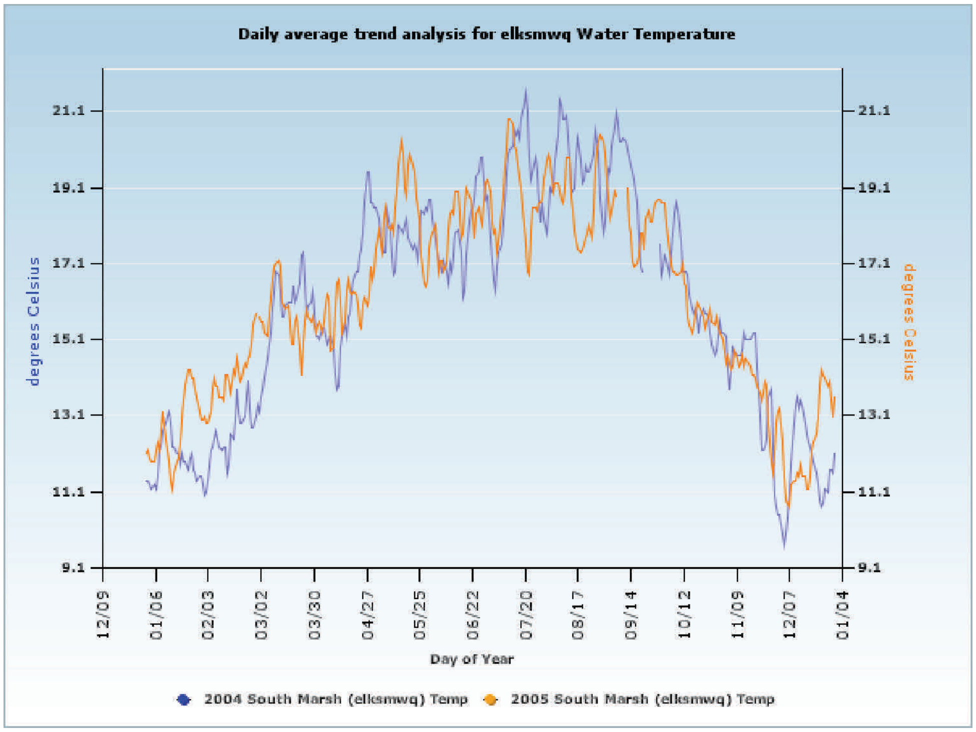

Figure 9.

Water temperature: South Marsh

pH

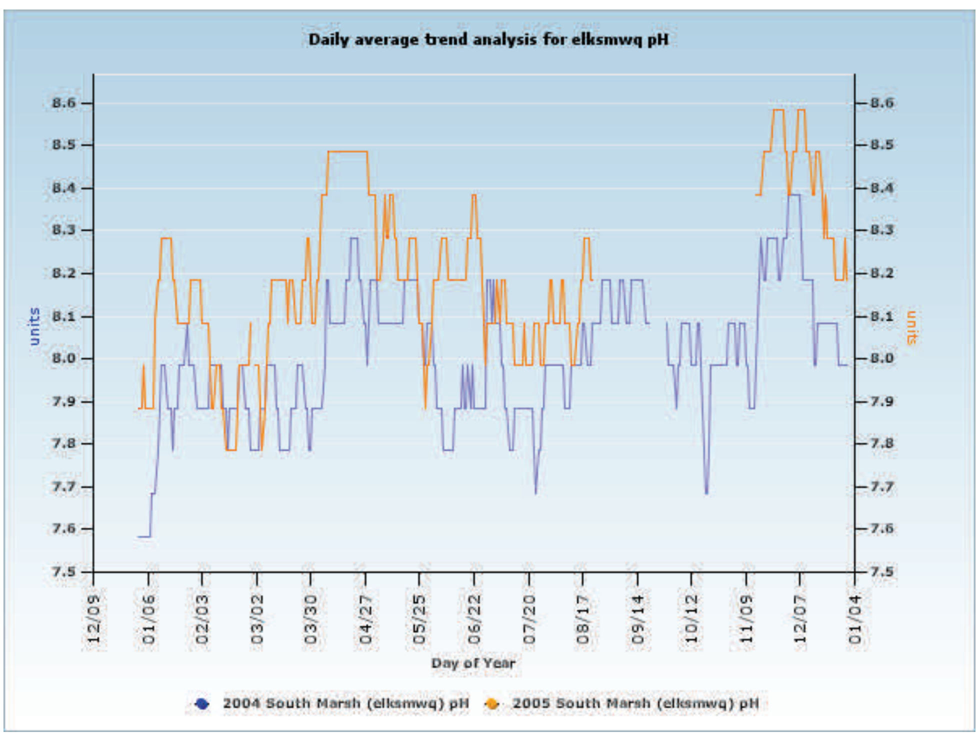

Figure 10.

pH: South Marsh