DATA IN THE CLASSROOM

MONITORING ESTUARINE WATER QUALITY

2nd Edition (2018)

This curriculum module was originally developed for the NOAA Ocean Data Education (NODE) Project. This 2nd edition (2018) was completed under contract by Amy Dean. Data in the Classroom is a collaboration of many NOAA programs and offices including: National Environmental Satellite, Data, and Information Service (NESDIS), National Estuarine Research Reserve System, National Oceanographic Data Center and the Office of National Marine Sanctuaries.

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INTRODUCTION

The lessons and accompanying data tools in this module will introduce students to *water quality monitoring* within our nation's estuaries, specifically the estuaries that are part of NOAA's National Estuarine Research Reserve System. Students will use real data to investigate the water quality characteristics of an estuary (water temperature, salinity and oxygen), the relationship between these parameters, and the effect that water quality has on the organisms living within the estuary. Ultimately, students will examine the impacts of physical water quality factors on species that live in a given environment, using the Atlantic sturgeon as an example. Although the lessons deal primarily with water temperature, dissolved oxygen, and salinity, students can use the online tools to extend their investigations by examining other parameters as well. The goal is for students to experience different kinds of data and data accessing tools, so that, by the end of the module, they can continue to explore data sets driven by their own inquiry.

The curriculum is not designed to be a comprehensive unit on estuaries or on water quality measures. Rather, the focus is on data literacy as much as science, and the lessons are intended to help achieve important cross-curricular connections between science and mathematics.

Estuary Basics

Estuaries are partially enclosed bodies of water where two different water bodies meet and mix. In an estuary, fresh water from rivers or streams mixes with salt water from the ocean (or with the chemically distinct water of a large lake). Estuaries are critically important, in part, because they provide breeding and nursery habitat for many different types of fish. However, because they occur where the land meets the sea, estuarine ecosystems are also some of the most impacted by human activities. For more background information about estuaries, visit NOAA's National Estuarine Research Reserve System website, Estuary Education.

Curriculum Overview

Water quality is often taught as a field project in which students measure water quality at a local stream or aquatic site. If you routinely conduct such local studies with your students, this module can serve as a complement to give students more exposure to real data. However, because of the challenges involved with field trips and the fact that not all schools have access to field sites, this module is also designed to be used as a stand-alone lesson. In this case, you can treat the module as a "virtual" or electronic field trip, in which students use real data from the internet to explore and monitor an aquatic environment without leaving the classroom.

This curriculum module offers activities at five different levels of student interaction, sometimes referred to as Entry, Adoption, Adaptation, Interactivity and Invention. Levels 1 and 2 are very directed and teacher driven. Levels 3-5 of Adaptation through Invention are more student directed and open up opportunities to design lessons featuring student inquiry.

The levels serve a dual purpose. They are designed to engage students in increasingly sophisticated modes of understanding and manipulating data. They are also intended to help you, as a teacher, familiarize yourself with online tools for accessing data and to provide you with models for integrating the use of real data into your classroom practice. The chart below illustrates the five levels of this module, *Monitoring Estuarine Water Quality.*

				5	**INVENTION: Designing Your Own Investigation:** Students will design their own plan to answer a research question.
			4	**INTERACTIVITY: Spawning of the Atlantic Sturgeon:** Students will evaluate water quality data to identify the optimal timing of springtime spawning migrations of the Atlantic sturgeon.	
		3	**ADAPTATION: Introducing Salinity:** Students will apply data skills to examine variations in salinity in an estuary. This activity uses guided inquiry and investigation design.		
	2	**ADOPTION: Understanding Dissolved Oxygen:** Students will use data to examine the relationship between water temperature and dissolved oxygen. This teacher-directed activity applies pre-existing models and provides practice reading data.			
1	**ENTRY: Analyzing Water Quality Data –** Students will analyze water temperature data and identify daily and seasonal temperature patterns in estuaries around the United States. This is a teacher-led activity.				

Next Generation Science Standards (NGSS)

This module was developed to build data literacy, engaging students in increasingly sophisticated modes of understanding and manipulation of data. In 2018, the module was updated and adapted to incorporate the innovations described in the NGSS[1] where possible. An alignment document has been developed to help teachers and educators understand how the activities in this module align with the new standards. You can learn more about how this module relates to specific NGSS components by visiting the Data in the Classroom website.

Ocean Literacy

This curriculum module also supports the following Essential Principles of Ocean Sciences.[2]

1. The Earth has one big ocean with many features.

    f. The ocean is an integral part of the water cycle and is connected to all of the earth's water reservoirs via evaporation and precipitation processes.

5. The ocean supports a great deal of diversity of life and ecosystems.

    f. Ocean habitats are defined by environmental factors. Due to interactions of abiotic factors such as salinity, temperature, oxygen, pH, light, nutrients, pressure, substrate, and circulation, ocean life is not evenly distributed temporally or spatially, i.e., it is "patchy." Some regions of the ocean support more diverse and abundant life than anywhere on Earth, while much of the ocean is considered a desert.

    i. Estuaries provide important and productive nursery areas for many marine and aquatic species.

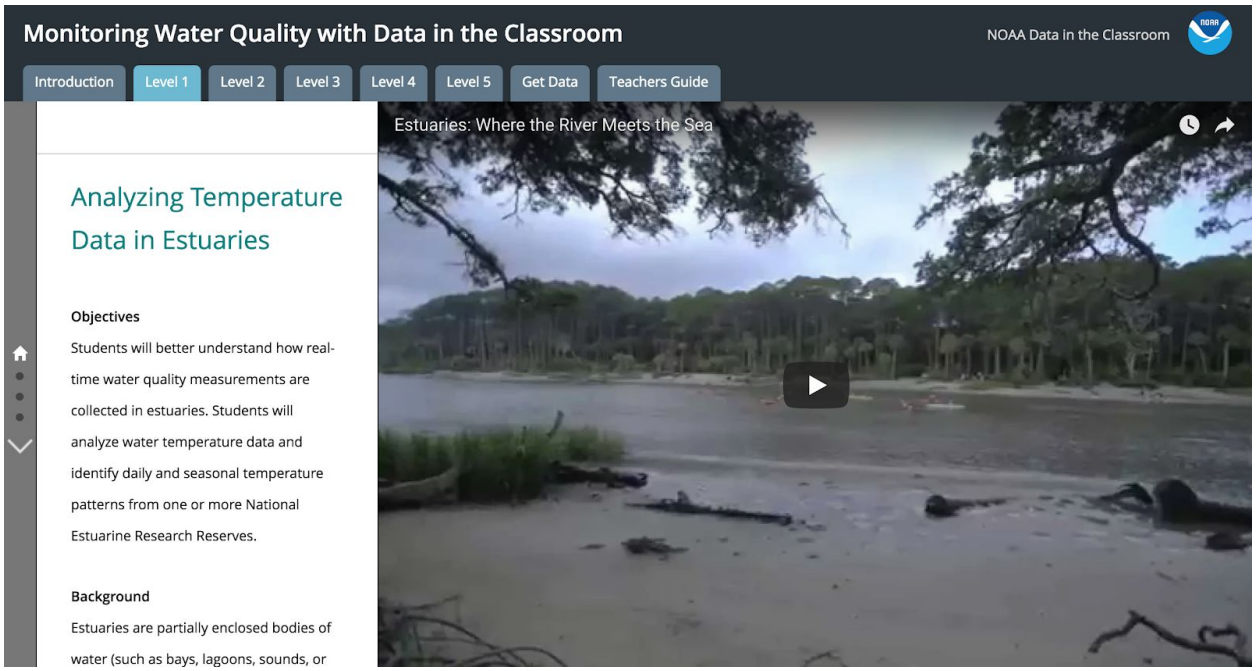
6. The ocean and humans are inextricably interconnected.

    f. Coastal regions are susceptible to natural hazards (such as tsunamis, hurricanes, cyclones, sea level change, and storm surges)

1 NGSS Lead States. 2013. Next Generation Science Standards: For States, By States. Washington D.C.: The National Academies Press. Next Generation Science Standards 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.

2 Ocean Literacy Network (2005). Ocean Literacy - The Essential Principles of Ocean Sciences K-12. Washington, D.C.

LEVEL 1: ENTRY
ANALYZING WATER QUALITY DATA



SUMMARY

- Grade Level: 6-8
- Teaching time: 45 minutes
- Activities: a) explore some of the estuaries within our nation's NERR System and b) interpret graphs of water temperature data
- Vocabulary:
    - *Data logger* – an instrument used to measure water quality parameters.
    - *Estuary* – a partially enclosed body of water (such as a bay, lagoon, sound, or slough) where two other bodies of water, usually saltwater and freshwater, meet and mix.

LESSON PLAN – LEVEL 1

Objectives

Students will be understand how real-time water quality measurements are collected in estuaries. Students will analyze water temperature data and identify daily and seasonal temperature patterns from one or more National Estuarine Research Reserves.

Background

Water quality describes the condition of the water - including characteristics such as temperature, the amount of salt (salinity), the amount of dissolved oxygen and nutrients, and contaminants such as pesticides from human activities. Good water quality is essential to the health of our nation's estuaries, much like clean drinking water and air quality are essential to the health of people.

Water quality conditions are monitored in each of the National Estuarine Research Reserves using instruments called *data loggers*. These loggers continuously track water quality conditions in an estuary like the Chesapeake Bay and help scientists to understand how water quality conditions change over time. If oxygen, temperature or other conditions fall outside of what's 'normal' for a given time period, the health of animals and plants living within the estuary could be at risk.

Why study water temperature? The temperature of water in an estuary is an important indicator of the health of aquatic systems, and as described in Level 2, temperature is also of importance because of the direct relationship between water temperature and how much oxygen can be dissolved into the water. The temperature of the water also determines 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. If the water in the estuary is outside the normal seasonal temperature range for which the local organisms are adapted, it is probably an indication that something is adversely affecting the health of the estuary.

Materials

- Projector
- Computers and internet access
- Photocopies of student worksheets (optional)

Teacher Prep

There are a variety of ways to implement this activity. Decide which works best for your classroom, and prepare as appropriate.

- Go the the Data in the Classroom website and familiarize yourself with the Level 1 activities.
- If your students have computers and internet access, you may choose to have them complete the online student activities during this lesson.
- If you do not have internet access in your classroom, you can alternatively use the student worksheet at the end of this lesson in place of the online activities.

Procedure

Introduction:

Engage students in this module by explaining that they will be looking at an important issue – water quality monitoring and the health of our nation's estuaries.

1. Navigate to the *Monitoring Estuarine Water Quality* online activities. Click on the *Level 1* tab.
2. Play the short 2-minute video.
    - After watching the video, students should be able to define an estuary, name a few reasons why estuaries are important, and broadly describe why we have a system of National Estuarine Research Reserves.

Part 1 - What Is Water Quality? How is It Measured?

Before students can start using data to understand water quality, they need to learn how water quality parameters, such as temperature, are continuously monitored.

1. Scroll down to the next section in Level 1, titled 'What is Water Quality? How Is It Measured?' Use a projector to show the interactive map of the estuaries within the National Estuarine Research Reserve System. Locate and explore the estuaries of interest to you and your students.

2. Give students time to answer the question at the end of this section.
   Answer - Question 1: B - Water temperature

Part 2 - Analyzing Seasonal Water Temperature

1. Scroll down to the next section. Explain to students that they are going to take a "virtual" trip to the San Francisco Bay estuary to investigate water temperature. The red icons on the map show the locations of each of the four real-time data loggers that collect continuous water quality data.

2. Find the text in this section that says 'Click here.' Clicking this link will display water temperature data at one station from January - December 2017. If needed, explain how to read the graph (the axes, the legend, etc).

   - Demonstrate how to move your cursor over the line graph to display the temperature values.

3. Give students time to answer the questions at the end of this section.
   Answer - Question 2: A - January
   Answer - Question 3: C - June - September
   Answer - Question 4: 6 - 26 °C

4. Discuss water temperature variations over the course of the year. Ask students to identify and explain patterns in the data.
   Possible answers: There is a seasonal temperature pattern. The water temperature was lowest in the winter, then gradually rose to its highest level in late summer,

before falling again the next winter. Because estuaries are shallow bodies of water, large ranges in temperature can occur on a yearly basis.

Part 3 - What Causes Water Temperature to Change?

Many plants and animals are sensitive to relatively small temperature changes, 1-2 degrees above or below what they normally experience during a given season. What might cause water temperature in an estuary to become warmer or colder than the normal?

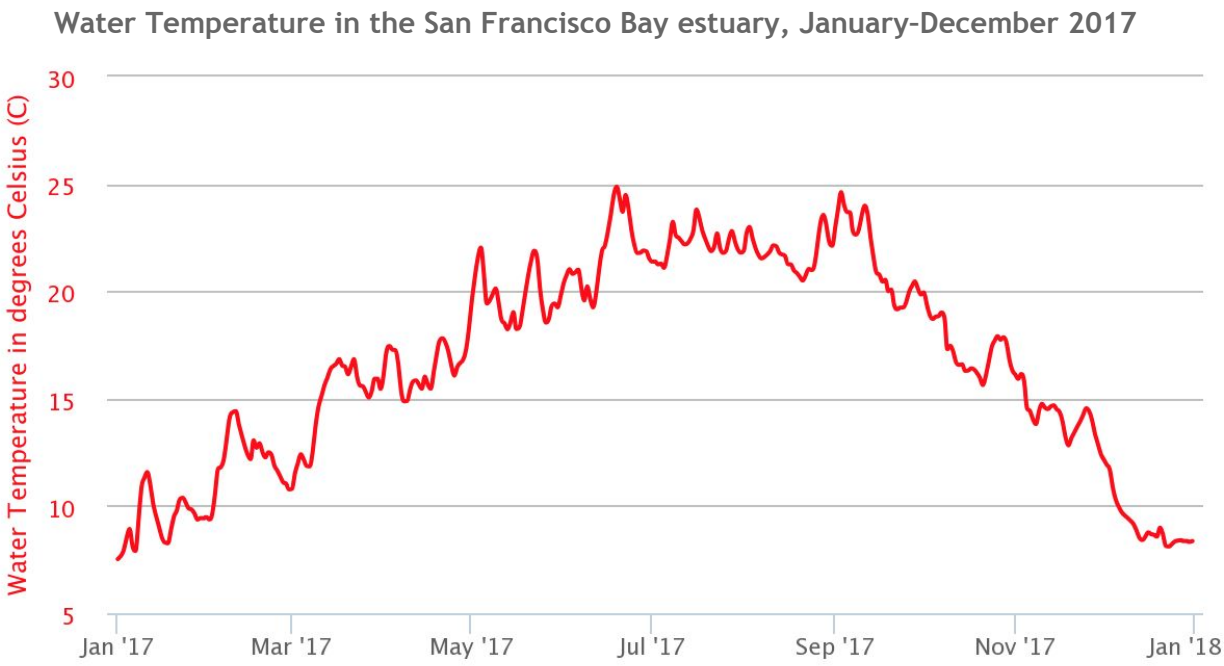
1. Scroll down to the next section. The graph shows water temperature data from the San Francisco Bay in the late summer (August 2017). This data is plotted with air temperature data from the same location.
    a. Locate the legend at the top of the graph.
        i. Click on the blue line, named *SFBFMWQ - Temp*. The blue line should disappear, leaving only the green 'air temperature' data visible.
        ii. Let students know that they can click inside the graph's legend to hide/unhide the data series. This may help them to read/interpret the graph.
    b. Explain how to read a graph with 2 y-axes.

2. Give students time to answer the questions at the end of this section.
   Answer - Question 5: B - water temperature increased by >2 °C
   Answer - Question 6: A - Water temperature and air temperature are directly related

3. Discuss: what might cause water temperature in an estuary to become warmer or colder than the normal?
   Possible answers: Rapid and extended periods of unusually cold weather or heat waves can cause water temperatures to fall or rise above what's 'normal,' affecting the organism that live in estuaries. For example, in the Chesapeake Bay region, severe, cold weather events have caused mass mortality of some fish species, like the speckled trout, during the winters of 2011 and 2014. Water temperature is also affected by global climate change. As average air temperatures rise, so do the water temperatures of our estuaries, affecting the species that live within them.

STUDENT WORKSHEET – LEVEL 1

ANALYZING TEMPERATURE DATA IN ESTUARIES

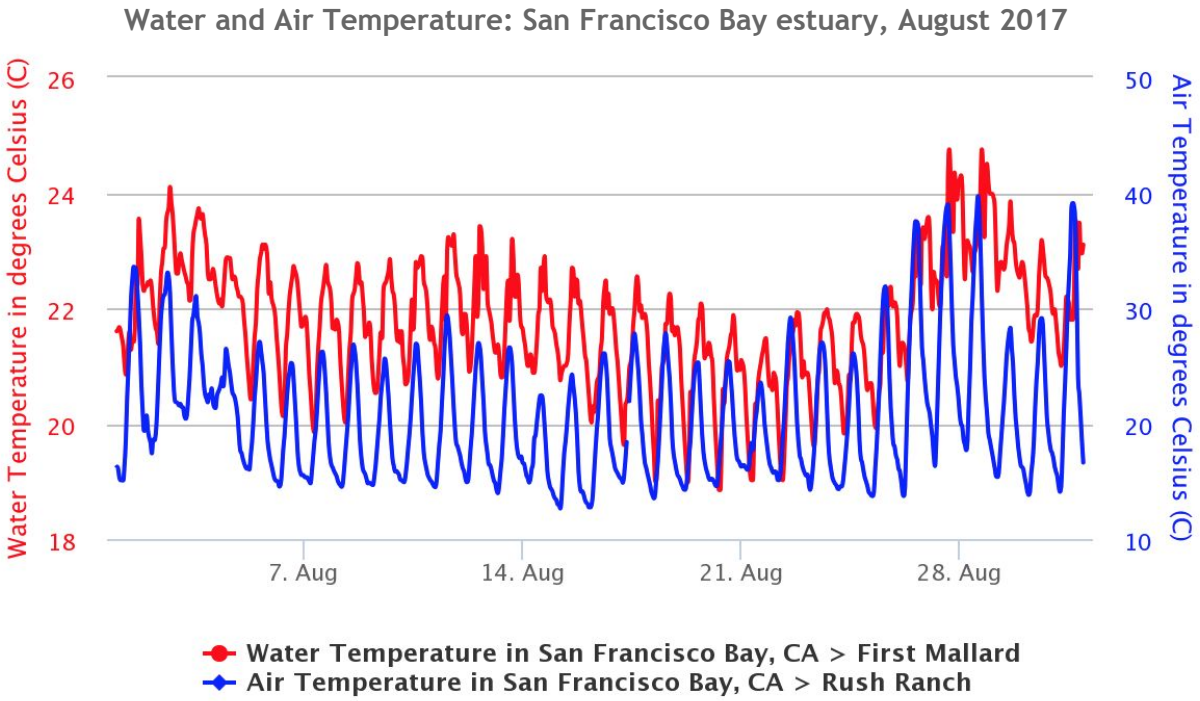


<u>Part 1: Instructions:</u> Use the graph above to answer the following questions:

1. The water temperature was lowest during which month of the year?
   A. January
   B. February
   C. June
   D. December

2. Water temperature was highest during the following months:
   A. January-March
   B. May-August
   C. June-September
   D. August-October

3. Any fish that lives at this location throughout the year would have to be well-adapted to temperatures ranging from approximately _____ degrees C to _____ degrees C.



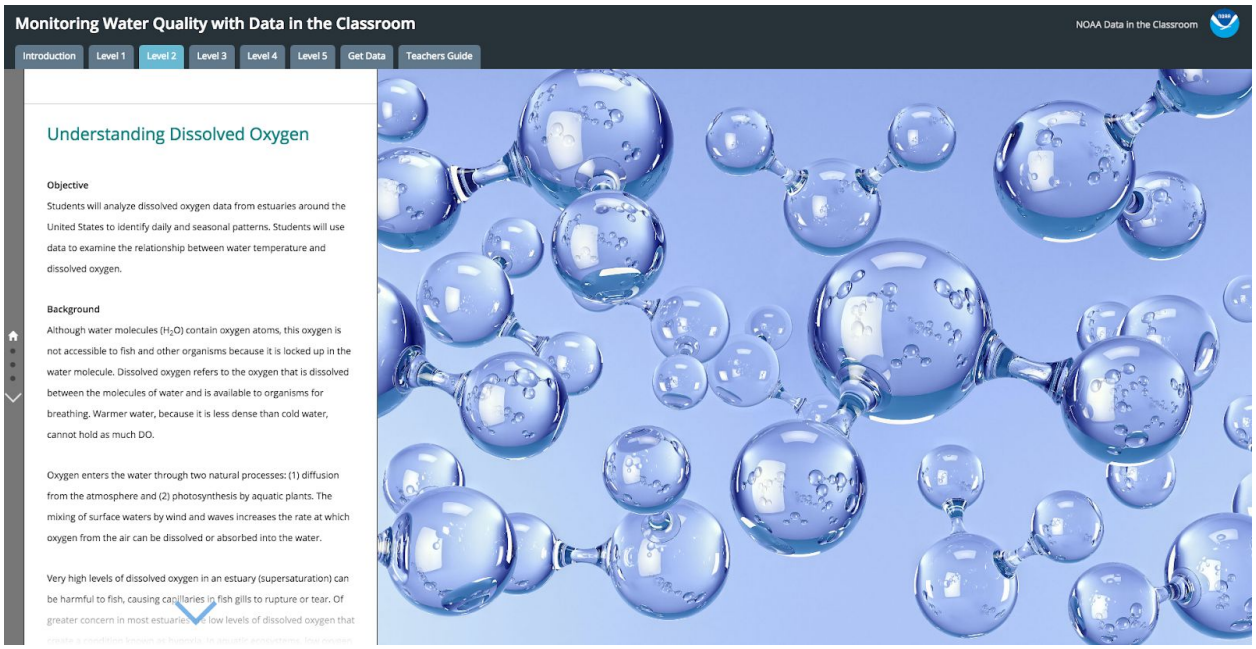
<u>Part II: Instructions:</u> Use the graph above to answer the following questions:

4. In late August 2017, a record-breaking heat wave hit the San Francisco Bay area, causing air temperatures to soar above 38°C (100 °F). Use the data to describe the apparent effect of the heat wave on water temperature at this location.

5. When water temperatures rise (or fall) above what is normal, how might organisms be affected?

6. How might an estuary, and the organisms living within it, be impacted by global climate change?

LEVEL 2: ENTRY
UNDERSTANDING DISSOLVED OXYGEN



SUMMARY

- Grade Level: 6-8
- Teaching time: 45 minutes
- Activities: a) Explore two processes that influence dissolved oxygen concentrations and b) create and analyze graphs to examine the relationship between water temperature and dissolved oxygen.
- Vocabulary:
    - *Dissolved oxygen* – oxygen from the surrounding atmosphere that is absorbed in water and supports aquatic life.
    - *Aquatic respiration* – the process by which aquatic animals take up and use dissolved oxygen from the water.
    - *Hypoxia* – an environmental phenomenon where the concentration of dissolved oxygen in the water column decreases to a level that can no longer support living aquatic organisms.

LESSON PLAN – LEVEL 2

Objectives

Students will analyze dissolved oxygen data from estuaries around the United States to identify seasonal patterns. Students will use data to examine the relationship between water temperature and dissolved oxygen.

Background

Although water molecules (H_2O) contain oxygen atoms, this oxygen is not accessible to fish and other organisms because it is locked up in the water molecule. Dissolved oxygen refers to the oxygen that is dissolved between the molecules of water and is available to organisms for breathing.

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.

In this activity, students will examine daily and seasonal patterns in dissolved oxygen concentrations within an estuary. The amount of dissolved oxygen in estuary waters varies naturally. Daily variations are due to changes in the tides, in temperature, and in the photosynthetic activity of plants. Students should notice that oxygen levels typically peak during the daylight hours as plants are photosynthesizing. At night oxygen levels decrease because plants stop photosynthesizing and both plants and animals are respiring.

Seasonal and monthly fluctuations in dissolved oxygen are related to the tides, day lengths, and temperatures. Temperature affects the solubility of oxygen in water, and students should notice that dissolved oxygen concentrations are inversely related to water temperature. Because oxygen is a gas, it tends to escape from water when heated. As a result, cold water is capable of absorbing more oxygen than is warm water. The relationship between seasonal water temperature and dissolved oxygen make them both important indicators of habitat quality for many estuary species.

Very high levels of dissolved oxygen in an estuary (supersaturation) can be harmful to fish, causing capillaries in fish gills to rupture or tear. Of greater concern in most estuaries are low levels of dissolved oxygen that create a condition known as hypoxia. Hypoxic conditions in an estuary (due primarily to nutrient pollution from agricultural runoff, sewage spills, the burning of fossil fuels) may cause die-offs of fish, shellfish, corals, and aquatic plants. In aquatic ecosystems, low oxygen usually means a concentration of less than 2-3 milligrams of oxygen per liter of water (mg/l). The number of U.S. estuaries experiencing hypoxia has greatly increased in recent decades, and over half of these exhibit hypoxic conditions in any given year. Students can investigate hypoxic conditions in estuaries around the United States in Level 5 of this module.

Materials

- Projector
- Computers and internet access
- Photocopies of student worksheets
- Optional: If you have a dissolved oxygen test kit, you can prepare a demonstration to show students how dissolved oxygen is measured in the field.

Teacher Prep

There are a variety of ways to implement this activity. Decide which works best for your classroom, and prepare as appropriate.

- Go the the Data in the Classroom website and familiarize yourself with the Level 2 activities.
- If your students have computers and internet access, you may choose to have them complete the online student activities during this lesson.
- You can use the student worksheet at the end of this lesson in conjunction with, or in place of, the online activities.

Procedure

Introduction:

- Navigate to the *Monitoring Estuarine Water Quality* online activities. Click on the *Level 2* tab.
- Explain to students that dissolved oxygen enables living organisms to survive underwater. Aquatic animals, like humans, need oxygen to survive.
- Ask: How do you think oxygen gets into the water?
  Answer: Oxygen can slowly diffuse across the water's surface from the atmosphere. It is also produced through the process of photosynthesis by aquatic plants and algae.

Part 1 - Graphing Dissolved Oxygen

Here, students will learn to use the online data tool to explore seasonal changes in dissolved oxygen concentrations at ACE Basin, South Carolina. If desired, conduct this activity using data from an estuary that is closest to where you live.

1. Scroll down to the section in Level 2, titled 'Graphing Dissolved Oxygen.' Use a projector to show the interactive map of the estuaries within the National Estuarine Research Reserve System.
2. Locate ACE Basin, South Carolina on the map.
3. Follow the step-by-step instructions to create a graph from January - December 2017. If needed, explain how to read the graph (the axes, the legend, etc).
   a. Demonstrate how to move your cursor over the line graph to display the dissolved oxygen values.
4. Students may notice a lot of variability in the data. They may also notice that there are some periods over the course of the year when data were absent. Missing data could be due to errors or malfunctions with the monitoring instruments.

5. Give students time to answer the questions at the end of this section.
   Answer - Question 1: C - 10 mg/L
   Answer - Question 2: D - September

6. Ask: How did dissolved oxygen change over the course of the year?
   Possible answers: There is a lot of variability (ups and downs) in the data. Despite this, there is a noticeable seasonal pattern. Dissolved oxygen was lowest in the late summer and fall, highest during the winter and early spring.

Part 2 - What Affects Dissolved Oxygen?

1. Scroll down to the next section. Describe what happens when a gas like oxygen heats up. As temperature increases, the gas molecules have more energy and move faster. Ask students whether they would expect warm water to contain more or less dissolved oxygen than cold water.
   Answer: Warm water would contain less dissolved oxygen than cold water.

2. Tell students they will look at the ACE Basin estuary in South Carolina to answer the question: How might changing water temperatures affect dissolved oxygen?

3. Add water temperature data to the 2017 dissolved oxygen graph by following the steps outlined in the online activity.

   - Explain how to read a graph with a secondary y-axis, if needed.

4. Give students time to answer the questions at the end of this section.
   Answer - Question 3: A - highest; lowest
   Answer - Question 4: D - When temperatures increased, dissolved oxygen levels decreased

5. Discuss: what is the relationship between water temperature and dissolved oxygen?
   Possible answers: Seasonally, there is an inverse relationship between water temperature and dissolved oxygen. When water temperatures are highest in late summer, dissolved oxygen levels are at their lowest.

Part 3 - What Else Affects Dissolved Oxygen?

Finally, students will explore changes in dissolved oxygen concentrations over a two-day period, instead of over an entire year.

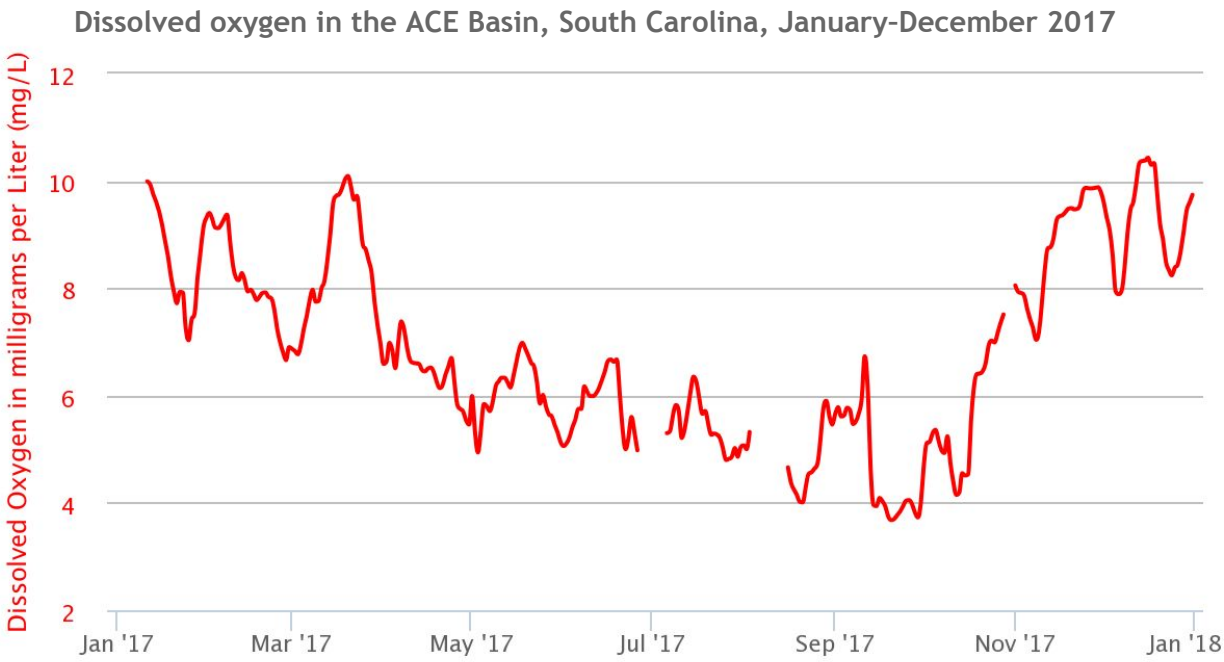
1. Make changes to the graph by following the steps outlined in the online activity.

2. Discuss: Describe the relationship between water temperature and dissolved oxygen in this graph. Is this what you expected? Why or why not?
   Possible answers: Your students should notice that there is an apparent direct relationship between dissolved oxygen and temperature over a two-day period. This is probably not what they might expect, because the previous graph showed an inverse relationship between water temperature and dissolved oxygen. This is because the concentration of dissolved oxygen in water is influenced by a number of factors, including water temperature. Cold water is able to "hold" more dissolved oxygen during the winter months, and the warmer water of summer can "hold" less dissolved oxygen.

3. Explain: Propose an explanation for the daily fluctuations in dissolved oxygen at ACE Basin on August 1-3, 2017.
   Possible answers: Over this short time period, daily variations in dissolved oxygen are affected by the photosynthetic activity of plants. Oxygen levels typically peak during the daylight hours as plants are photosynthesizing. At night, oxygen levels decrease because plants stop photosynthesizing and both plants and animals are respiring. Here, temperature has less of an effect on dissolved oxygen concentrations because the differences in daytime and nighttime temperatures are fairly small (~ 2 °C) compared with differences in summer and winter temperatures (~ 20 °C).

STUDENT WORKSHEET – LEVEL 2

ANALYZING DISSOLVED OXYGEN IN ESTUARIES



<u>Part 1: Instructions:</u> Use the graph above to answer the following questions:

1. Approximately, how much dissolved oxygen was in the water at ACE Basin on January 5, 2017?
   A. 6 mg/L
   B. 8 mg/L
   C. 10 mg/L
   D. 12 mg/L

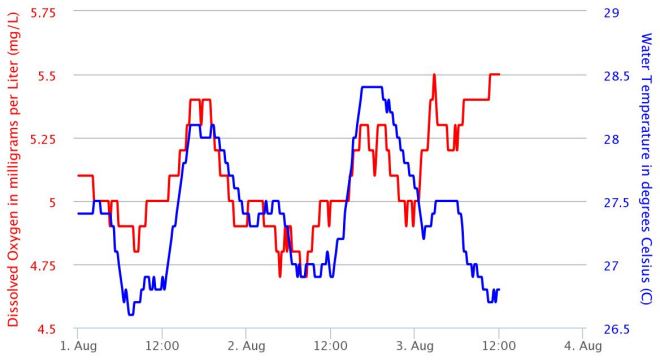
2. Dissolved oxygen concentrations were lowest during which month?
   A. January
   B. July
   C. August
   D. September

3. A fish that lives in the ACE Basin year round would have to be well-adapted to dissolved oxygen concentrations ranging from approximately _____mg/L to _____ mg/L.

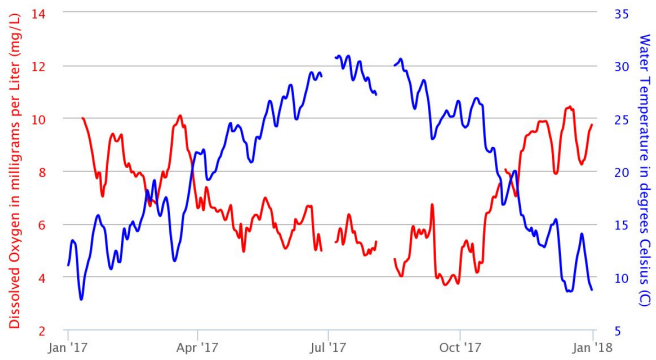
Comparing Daily and Seasonal Relationships:

Water Temperature and Dissolved Oxygen in the ACE Basin, South Carolina

August 01-03, 2017



January - December 2017



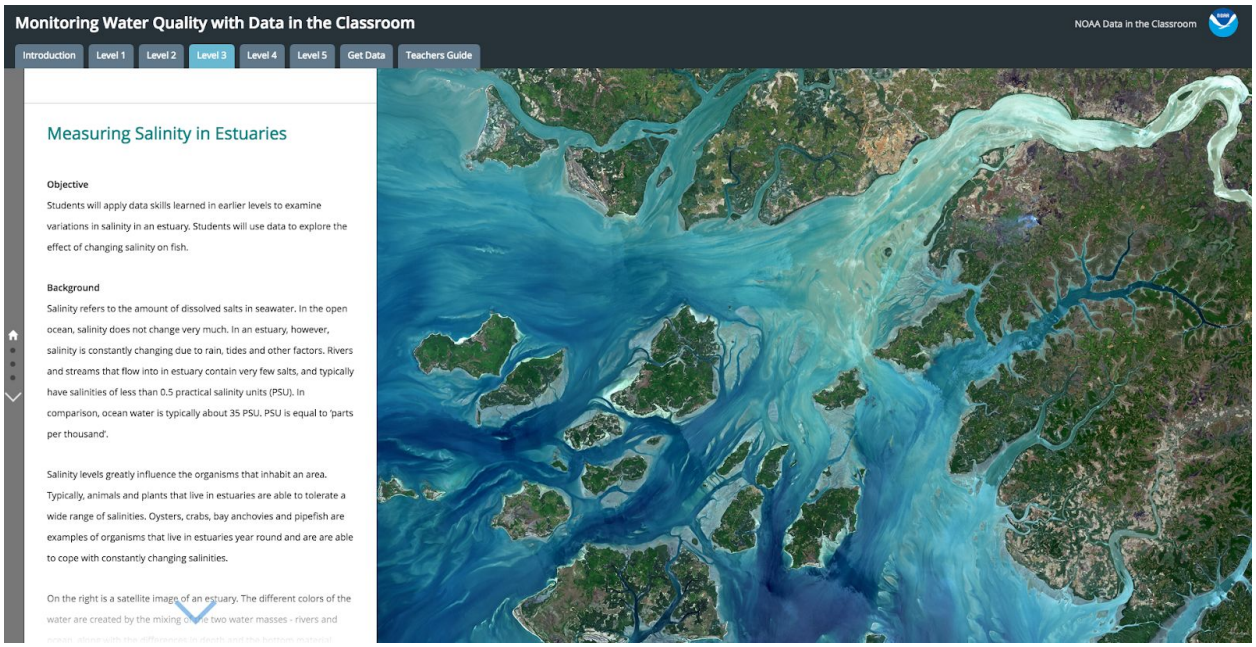
<u>Part II: Instructions:</u> Use the graph above to answer the following questions:

1. The first graph shows fluctuations of water temperature and dissolved oxygen over a 2-day period, August 1 - 3, 2017.
   A) On each day, what time of day was water temperature highest?
   B) What time of day was dissolved oxygen highest?

2. A) Describe the relationship between water temperature and dissolved oxygen in the first graph.
   B) Is this what you expected? Why or why not?
   C) Propose an explanation for the daily fluctuations in dissolved oxygen at ACE Basin on August 1-3, 2017.

3. A) Describe the relationship between water temperature and dissolved oxygen in the second graph.
   B) What might explain the apparent difference in the relationship of water temperature and dissolved oxygen in the two graphs?

LEVEL 3: ADAPTATION
MEASURING SALINITY IN ESTUARIES



SUMMARY

- Grade Level: 6-8
- Teaching time: Two 45-minute teaching periods
- Activities: Students will analyze data within an estuary to determine the effect of tides and precipitation on salinity as well as to predict the effect of changes in salinity on fish.
- Vocabulary:
    - *Salinity* – the amount of dissolved salts in seawater, measured in Practical Salinity Units (PSU). In the ocean, salinity is approximately 35 PSU. Rivers and streams contain very few salts and are typically less than 0.5 PSU.

LESSON PLAN – LEVEL 3

Objectives

Students will apply data skills learned in earlier levels to examine variations in salinity in an estuary. Students will use data to explore the effect of changing salinity on fish.

Background

Salinity refers to the quantity of dissolved salts in seawater, measured in Practical Salinity Units (PSU). PSU is a scale based on seawater conductivity. 1 PSU is equivalent to approximately 1 gram of salt per 1000 grams of water.

In the open ocean, salinity does not change very much. Why? Simply put, the ocean is really big. Any fresh water or extra salts that drain into the vast ocean won't change the salinity very much. In an estuary, however, salinity is constantly changing. Rivers and streams (and precipitation) bring freshwater into estuaries. Salty ocean water ebbs and flows into estuaries with the tides.

In an estuary, salinity levels are generally highest near the mouth - where the ocean water enters. Salinity levels are lowest upstream where freshwater flows in. However, salinities at specific locations in the estuaries vary through the tidal cycle. Overall salinity levels in the estuaries decline in the spring, when snowmelt and rain produce elevated freshwater flows from streams and groundwater.

Salinity levels greatly influence the organisms that inhabit an area. Typically, animals and plants that live in estuaries are able to tolerate a wide range of salinities. Cordgrass, pickleweed, oysters, blue crabs, bay anchovies and pipefish are examples of organisms that live in estuaries year round and are are able to cope with constantly changing salinities.

Materials

- Projector
- Computers and internet access
- Photocopies of student worksheets

Teacher Prep

There are a variety of ways to implement this activity. Decide which works best for your classroom, and prepare as appropriate.

- Go the the Data in the Classroom website and familiarize yourself with the Level 3 activities.
- Use the student worksheet at the end of this lesson in conjunction with the online activities.

Procedure

Engage students in this lesson by explaining that salinity is one of the most useful and commonly measured water quality parameters. In estuaries, salinity is constantly changing due to tides, precipitation, evaporation or man-made pollution. However, if salinity changes too much (outside of what's normal for a given area) it can be very detrimental to water quality.

Part 1 - Salinity in an estuary

1. Navigate to the *Monitoring Estuarine Water Quality* online activities. Click on the *Level 3* tab. Scroll down to the section titled, 'Salinity in an Estuary.'
2. Remind students about the structure of an estuary by using the map of Waquoit Bay National Estuarine Research Reserve. This estuary is located on the southern shore of Cape Cod, MA. Point out the location of the ocean, as well as the streams and rivers that bring fresh water to the estuary.
3. Define salinity as the amount of dissolved salts in the water. Salinity measurements are reported based on the unitless Practical Salinity Scale (PSU). The average ocean salinity is 35 PSU and the average salinity in a river or stream is 0.5 PSU or less.
4. Give students time to answer the questions at the end of this section.
   Answer - Question 1: Childs River
   Answer - Question 2: 15 PSU
5. Locate the mouth of the Childs River on the map. Ask the students to predict what the measured salinity might be at this location. How might tides influence salinity?

Possible answers: This location is relatively close to the ocean. On a rising tide, the salinity might be close to 35 PSU. On a falling tide, the salinity might be closer to 15 PSU.

6. Ask: Other than tides, what factors might influence salinity in an estuary?
   Possible answers: Freshwater inflow from rivers and streams, precipitation, evaporation and even wastewater discharge from sewage treatment plants.

Part 2 - Analyzing Salinity Data

1. Scroll down to the next section.

2. Tell students they will be taking a virtual trip to Waquoit Bay in Massachusetts to sample salinity.

3. Locate and select Waquoit Bay on the map. A list of 'monitoring stations' should appear. Below this list, a satellite map shows the location of each station within the bay. Find the station, Metoxit Point, located in the middle of Waquoit Bay. *Note: water quality stations are marked with water droplet icons.*

4. Create the graph by following the steps outlined in the online activity.

   - Explain how to read the graph (legend, axes, etc), if necessary.

   - Demonstrate how to move your cursor over the line graph to display the salinity values.

5. Give students time to answer the questions 3 and 4.
   Answer - Question 3: D - 27-30 PSU
   Answer - Question 4: A - Tides

6. Discuss any patterns in the data with students. The graph shows a regular daily pattern of increasing and decreasing salinity. However this pattern changes at the end of the month when salinity dips to 27 PSU on 10/27/2017. It is unlikely that tides caused this comparatively large decrease in salinity. Ask students to make their own predictions about what may have caused this change.

7. One factor that influences salinity is rain (precipitation). Add 'precipitation' data to your existing graph by following the steps outline in the online activity.

8. Give students time to answer the question 5.
   Answer - Question 5: C - A rainstorm on October 25th may have caused the decrease in salinity on October 27th.

9. Ask the students to summarize the salinity data, describe any patterns in the data and propose explanations for the small and large variations in the data.
   Example: The salinity of the water at this location ranged between 27 and 30 PSU. Salinity rises and falls daily, increasing and decreasing by approximately 1 PSU. These changes are likely caused by tides. The larger decrease in salinity at the end of the month may have been caused by a rainstorm. Precipitation data supports this claim.

Part 3 - Answering a Question with Data

1. Scroll down to the next section of the online Level 3 activity, 'Answering a Question with Data.'
2. Pair up students into teams and give each team a copy of the student worksheet at the end of this section. Review the scenario and the question.
3. In the online activity, select 'click here' next to the heading 'Get the data.' Explore the map of the San Francisco Bay estuary, using the interactive tool.
   a. Point out the delta and the major rivers (Sacramento and San Joaquin) that flow into the bay from the east. Delta smelt are endemic to the freshwater areas around the Delta.
   b. Locate the Pacific Ocean and the mouth of the San Francisco Bay.
   c. Locate the four monitoring stations (indicated by water droplets icons). It may be necessary to zoom out or move/center the map to see the entire bay.
   d. Locate China Camp station. It is closer to the mouth of the bay and the water is much saltier here than the water near the Delta. Delta smelt are extremely rare in the saline water around China Camp.

4. Students should discuss what data they will need to answer the question, and then complete the table on their worksheet.
   Example of data may include: China Camp station, salinity data, 2/01/2017 - 02/28/2017

5. Student teams can access the data using the online data tool. After reviewing their data, students can write a detailed interpretation of what their data show and complete the conclusion statement at the end of the worksheet.

6. Successful data interpretations and conclusions may include the following:

    a. An accurate description of salinity data at China Camp, February 2017.

    b. An ability to draw connections between the low salinity (0-2 PSU) conditions at China Camp in February 2017 with the unusual appearance of the Delta smelt.

    c. Comparison of salinity data at China Camp station throughout 2017, concluding that salinity was unusually low in February.

    d. A clear understanding that salinity changes in time and space in an estuary; these changes can affect the distribution of organisms like the Delta smelt.

STUDENT WORKSHEET – LEVEL 3

Answering a Question with Data

It's February 2017. A number of endangered fish, called Delta Smelt, have recently been found in the San Francisco Bay, near China Camp station. These fish are usually found in the freshwater rivers that connect to the bay, where salinity is 2 PSU or less. They are almost never found in the salty waters near China Camp.

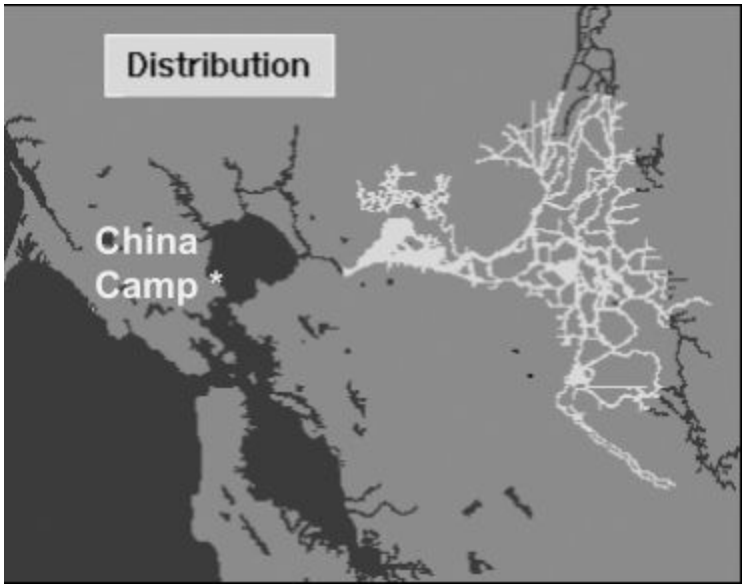


Photo (top): the endangered Delta Smelt

Map (bottom): the distribution of the the Delta Smelt (light gray) within the San Francisco Bay estuary.

Question: What may have caused Delta Smelt to be found outside of their normal range?

Make a Plan: What water quality data will you need? Fill in the table below.

Location (station name)	Water Quality Parameter(s)	Range of Dates

Get the data: Use the website to get the data needed to answer the question.

Interpret the data: What does your data show? Be specific and descriptive.

_____

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Draw a Conclusion: Delta smelt may have been found at China Camp in February 2017 because .....

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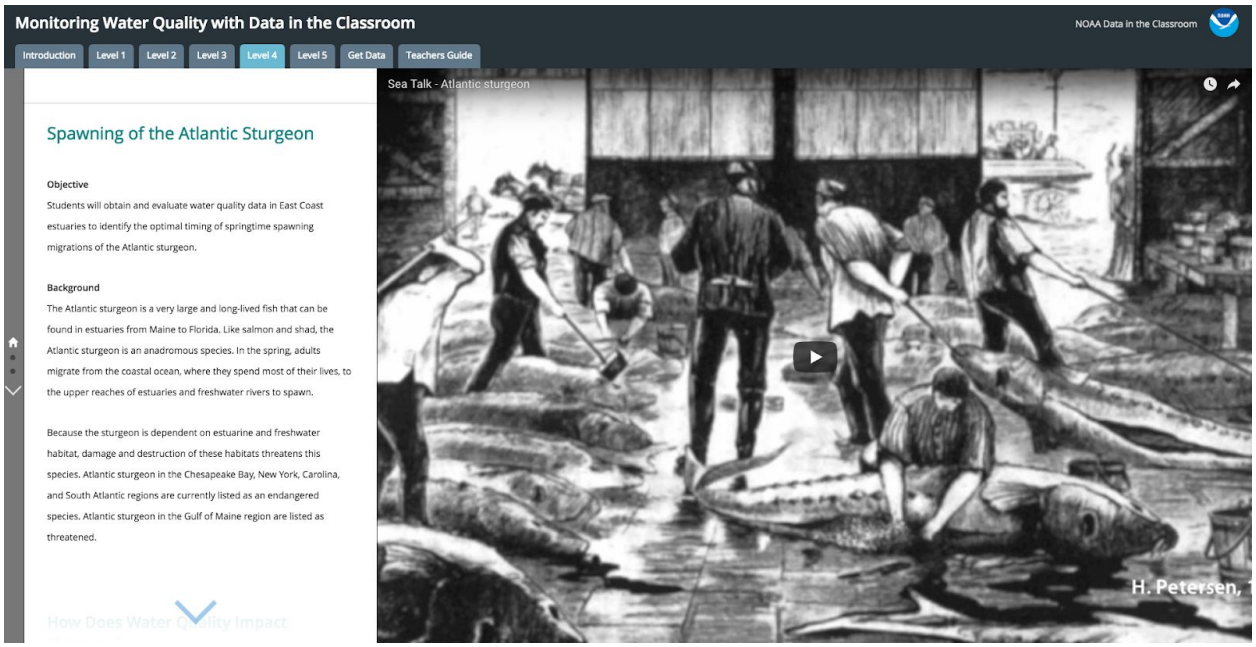
LEVEL 4: INTERACTIVITY
SPAWNING OF THE ATLANTIC STURGEON



SUMMARY

- Grade Level: 6-8
- Teaching time: Two 45-minute teaching periods
- Activities: Students will a) collect water quality data on several different parameters at a single location and b) interpret graphs of water quality data to answer a research question.
- Vocabulary:
    - *Anadromous* – migrating up rivers from the ocean to spawn.
    - *By-catch* - the unwanted fish and other marine creatures caught during commercial fishing for a different species.
    - *Migration* – the movement from one locality or climate to another for the purpose of feeding and breeding.
    - *Range* – an open region over which an organism may travel and feed.
    - *Spawn* – to produce and deposit eggs and produce young.

LESSON PLAN – LEVEL 4

Objectives

Students will obtain and evaluate water quality data in East Coast estuaries to identify the optimal timing of springtime spawning migrations of the Atlantic sturgeon.

Background

Estuaries are dynamic in nature. From prior data investigations in this module, students know that the water quality within estuaries, particularly temperature, salinity and dissolved oxygen, vary considerably over time. How do the changing physical conditions impact the animals that live in estuaries?

The Atlantic sturgeon is a very large and long-lived fish that can be found in estuaries from Maine to Florida. Like salmon and shad, the Atlantic sturgeon is an anadromous species. In the spring, adults migrate from the coastal ocean, where they spend most of their lives, to the upper reaches of estuaries and freshwater rivers to spawn.

Sturgeon are sensitive to water conditions during periods of spawning. For example, research has shown that specific water temperature cues cause sturgeon in U.S. South Atlantic estuaries to migrate earlier than those in mid-Atlantic and New England portions of their range.[1] This occurs, in part, because waters warm to the Atlantic sturgeon's optimal range earlier in the spring in the Southern Atlantic, later in the spring in the mid-Atlantic and New England.

Because the sturgeon is dependent on estuarine and freshwater habitat, damage and destruction of these habitats threatens this species. Other threats include water pollution, by-catch, and potentially, warming temperatures associated with climate change. Atlantic sturgeon in the Chesapeake Bay, New York, Carolina, and South Atlantic

1 K. E. Greene, J. L. Zimmerman, R. W. Laney, and J. C. Thomas-Blate, "Atlantic coast diadromous fish habitat: A review of utilization, threats, recommendations for conservation, and research needs," Atlantic States Marine Fisheries Commission Habitat Management Series (Washington, D.C., 2009).

regions are currently listed as an endangered species, and it is therefore illegal to fish for sturgeon (or take their eggs) in these areas. Atlantic sturgeon in the Gulf of Maine region are listed as threatened.

In this activity, students will use water quality data to answer a research question: *When will the Atlantic sturgeon most likely migrate into estuaries to spawn?* To accomplish this task, students must collect real water quality data along the Atlantic coast, using data loggers at in estuaries along the Atlantic Coast.

Understanding when spawning migrations are most likely to occur can help protect this species. For example, in some areas, the timing and location of Atlantic Sturgeon migrations overlap with commercial fishing activities. This may lead to sturgeon being caught unintentionally in the nets of commercial fisherman who are working in the area.[2] By understanding the timing of migrations of Atlantic Sturgeon in relation to commercial fishing, management agencies can better understand if there is a need to temporarily close fishing activities (or modify fishing nets) to reduce bycatch and give sturgeon populations a better chance to recover.

Materials

- Projector
- Computers and internet access
- Photocopies of student worksheets

Teacher Prep

- Navigate to the *Monitoring Estuarine Water Quality* online activities and familiarize yourself with the Level 4 activities. ***Note,*** depending on your location, you may wish to focus on a fish that is local to your area for the purpose of this investigation. The table on the next page
  provides a list of alternate species and resources.
- Students will need computers and internet access to complete this lesson.

2 K. J. Dunton et al., Marine Distribution and Habitat Use of Atlantic Sturgeon in New York Lead to Fisheries Interactions and Bycatch. Marine and Coastal Fisheries 7, 18-32 (2015).

Table 1: Fish species that can be used as alternatives to the Atlantic Sturgeon

Interested in focusing on a fish that is local to your area? Fish species in the table below undergo spawning migrations to estuaries or rivers and can be used in this activity in place of the Atlantic Sturgeon. Determine the specific water quality conditions that are optimal for spawning migrations by reviewing the fish fact sheets (links provided). Modify the investigation as needed.

Species	Estuaries	Fish Fact Sheet (hyperink)
Blueback Herring	*All East Coast estuaries in the NERR system: from Wells, ME to Guana Tolomato Matanzas, FL*	*Blueback Herring Fact Sheet* https://www.inaturalist.org/taxa/49225-Alosa-aestivalis
White Sturgeon	*South Slough, OR* *San Francisco Bay, CA* *Elkhorn Slough, CA*	*White Sturgeon Fact Sheet* *https://www.inaturalist.org/taxa/93194-Acipenser-transmontanus*

Procedure

Part 1: Background

1. Project the online activity in Level 4 and play the 1-minute video (Delaware Sea Grant, *Sea Talk, Atlantic Sturgeon*).

2. Explain that students will continue their investigations of water quality to answer the question, '*When will the Atlantic Sturgeon most likely migrate into estuaries to spawn?*'

Part 2 - How Does Water Quality Impact Sturgeon

1. Scroll down to the next section.

2. Explain that water quality conditions affect the health and behavior of organisms in many ways. This activity examines the spawning behavior of the Atlantic Sturgeon. Scientists studying sturgeon have discovered that specific water quality conditions cue sturgeon to begin their migrations from oceans into estuaries to spawn.

3. Give students time to review the online *Fact Sheet* and answer the question at the end of this section.
   Answer - Question 1: D - all of the above

Part 3 - Research Project: Predicting the Return of the Atlantic Sturgeon

1. Scroll down to the next section titled 'Research Project.' Here you'll find instructions and a defined question for students to answer using real water quality data.
2. Assign students to work in teams and give each team a copy of the Student Worksheet.
3. Each team should choose an estuary to focus on for their investigation. Teams can use the *Fact Sheet* and the online map to help them decide which estuary to select.
4. After students complete their research, provide time for each team to report its findings to the class.
5. As a class, keep track of the time periods that students identified for each estuary. You may wish to organize class findings into a table similar to the one below.

Example Table: Class findings - optimal timing for spawning migrations of the Atlantic Sturgeon based on regional water quality conditions.

Region	Estuaries	Time Period: when water quality conditions are best for spawning
Northern	*Wells, ME* *Great Bay, NH* *Waquoit Bay, MA* *Narragansett Bay, RI*	*May*
Mid-Atlantic	*Hudson Bay, NY* *Jacques Cousteau, NJ* *Delaware Bay, DE* *Chesapeake Bay, MD* *Chesapeake Bay, VA*	*April*
Southern	*North Carolina, NC* *ACE Basin, SC* *Sapelo Island, GA* *Guana Tolomato Matanzas, FL*	*February - March*

6. Discuss any patterns you might see in the findings. How do the time periods vary from north to south? How might populations of sturgeon in the different regions be affected by rising ocean temperatures associated with climate change?
   Possible answers: Students may find that optimal time periods for spawning in the northern regions are in late spring and early summer. Moving south, these time periods shift to early spring. Rising water temperatures associated with climate change may affect the sturgeon by impacting timing of spawning migrations, food availability, oxygen concentrations, and suitability of spawning habitat.
7. Ask students to discuss the following question: Why is it important to know when spawning migrations are most likely to occur? How can this ultimately help to protect the Atlantic Sturgeon?
   Possible answers: See the last paragraph in the *Background* section of this lesson.

STUDENT WORKSHEET – LEVEL 4

Research Question: Predicting the Return of the Atlantic Sturgeon

The Problem: Populations of Atlantic Sturgeon have been in decline over the past century. Estuaries are important for the survival of this species because sturgeon use them to spawn and have their young. The location and timing of their spawning migrations are therefore of primary importance.

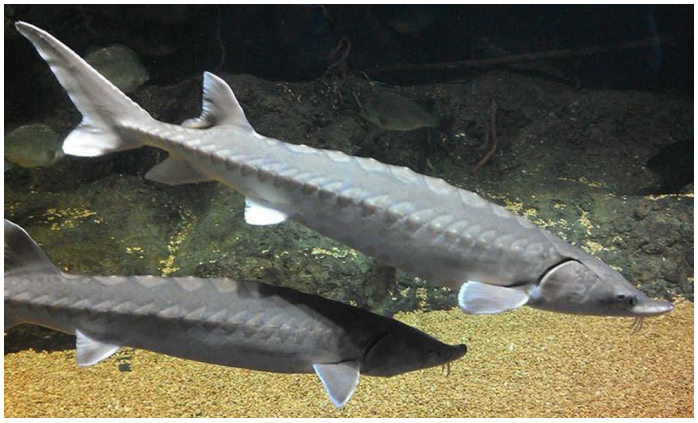


Photo (NOAA): the endangered Atlantic Sturgeon

Your mission: Your mission is protect the spawning populations of this species. To begin to do this, you will need to predict when Atlantic Sturgeon will migrate into the freshwater reaches of an estuary to spawn.

Which estuary?

- To get started, use the online *Fact Sheet* to select an estuary where Atlantic Sturgeon are found. Record the estuary name and location here: _____

Form Your Question: Write your research question in the space below.

Example: *In 2018, when will Atlantic Sturgeon most likely begin their spawning migrations into the Delaware Bay estuary?*

_____

_____

Get the data: To answer the question, determine what data you will need.

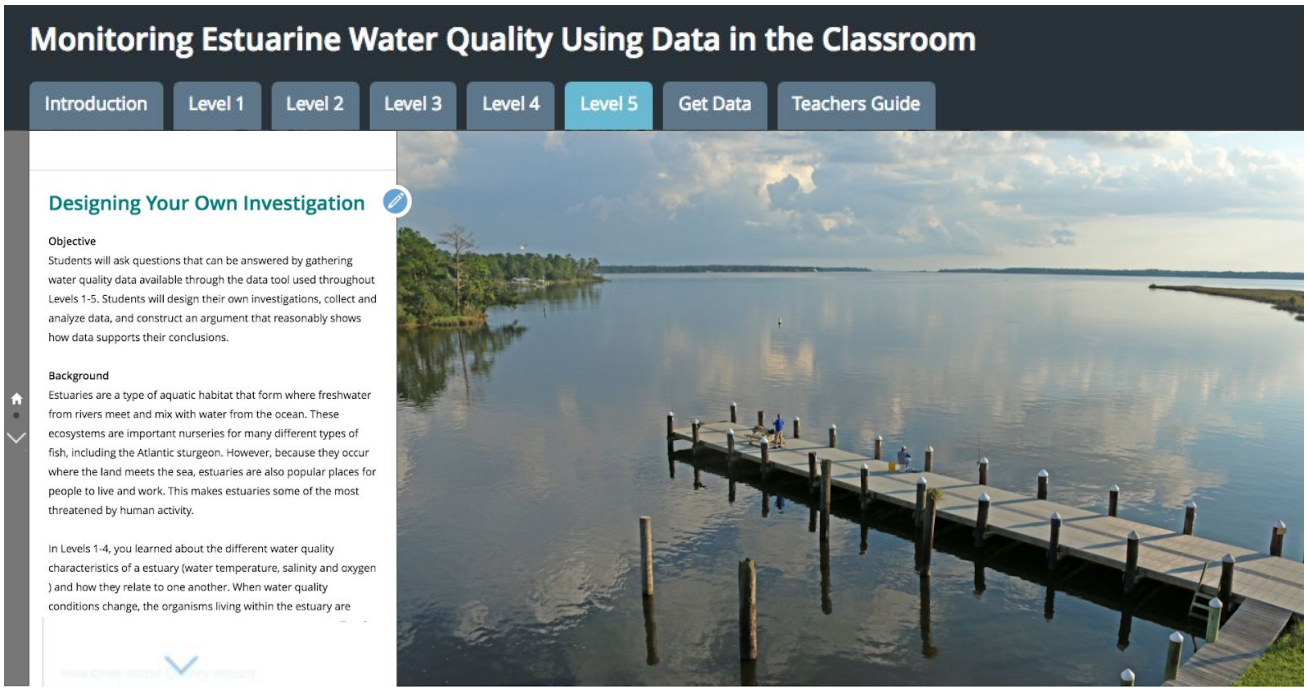
- Locate and select your estuary from the interactive map in Level 4.
- A list of monitoring stations should appear. Review the list. Choose any station(s) that collects 'water quality' data (avoid 'meteorological' and 'nutrient' stations)
- Click the 'Graph Data' icon. Select the parameters and dates you need to answer your question. Save or print your graphs, if desired.
- Use the table below to keep a record of the data you select, so you can refer to it later. The first row of data has been filled in, as an example.

Location (station name)	Water Quality Parameter	Range of Dates	Notes
Blackbird Landing	*Water Temperature*	*April 1-30, 2017*	*Temperatures were between 13-17°C throughout most of the month*

Analyze the data: Use your data table and graphs to answer the following questions:

1. Can you identify a time period when the water temperature is within the range for the sturgeon to return?
2. What is the range of the other water quality parameters during that time period?
3. Can you identify a time period when all the conditions look right for the sturgeon to return to spawn?
4. Do the same conditions occur around the same time, year after year?

LEVEL 5: INVENTION
DESIGNING YOUR OWN INVESTIGATION



SUMMARY

- Grade Level: 6-8
- Teaching time: Two 45-minute teaching periods
- Activities: Students will design and carry out an investigation using real water quality data.

LESSON PLAN – LEVEL 5

Objectives

Students will ask questions that can be answered by gathering water quality data available through the data tool used throughout Levels 1-5. Students will design their own investigations, collect and analyze data, and construct an argument that reasonably shows how data supports their conclusions.

Background

In Levels 1-4, students learned about the different water quality characteristics of a estuary (water temperature, salinity and oxygen) and how they relate to one another. Students also learned that water quality conditions affect organisms, like fish, that live in estuaries.

In Level 5, students should be encouraged to develop their own research questions and hypotheses. In general, questions that lead them to considering changes in water quality on a larger scale will provide a good starting point. Students can also extend their investigations by examining any of the water quality and weather parameters that are available through the data tool (nutrients, pH, turbidity and more). For more information about water quality, monitoring data and data collection methods, visit NOAA's National Estuarine Research Reserve System website, specifically the Estuary Science and Data webpage. The goal is for students to experience different kinds of data and data accessing tools, so that they can continue to explore data sets driven by their own inquiry.

Materials

- Projector
- Computers and internet access
- Photocopies of student worksheets

Teacher Prep

- Navigate to the *Monitoring Estuarine Water Quality* online activities and familiarize yourself with the Level 5 activities, sample questions and data tools.
- Practice generating graphs using the data tools in Level 5. Be prepared to demonstrate the tools for students.

Procedure

This activity challenges students to think like scientists by designing a scientific investigation in which data collection and analyses are important parts of the process. Students are challenged to engage in a number of scientific practices, including asking questions, analyzing data and constructing explanations using data.

1. Assign students to work in teams of two and give each team a copy of the student worksheet, *Design Your Own Investigation*.
2. Project Level 5 onto a screen and scroll down to the section titled 'Plan Your Investigation.' Locate the list of data tools.
3. Prior to developing a question, students will need to understand what types of data are available to them. Information about the data tool are described below. Instructions to use the tool can be found by clicking the 'Get Data' tab in the upper navigation bar. With students, discuss these data and demonstrate how to use the data tool, if needed.
    a. *NOAA's Water Quality Monitoring Tool* gives you access to real-time (and archived) water quality and weather data in each of the estuaries that make up the *National Estuarine Research Reserve System*.
    b. Students can use to tool to explore data and create graphs. Water quality parameters include: temperature, depth, salinity, dissolved oxygen, turbidity, and pH.

c. For more information about water quality, monitoring data and data collection methods, visit NOAA's National Estuarine Research Reserve System website, specifically the *Estuary Science and Data webpage*.

4. Guide student selection of a research question (or have them make up their own) that is appropriate to their academic experience. Sample questions are highlighted in the online Level 5 activities.

5. Next, in their small groups, students should determine what data are needed to answer their question, making a list on their worksheet.

6. Using the data tools on the website, students can then access, save and/or print the graphical displays of data. If necessary, help students determine if they have enough data to answer their question and identify areas where they may need to seek out additional sources of information.

7. After reviewing their data, students should work together to write a detailed interpretation of what their data show and complete the conclusion section at the end of the worksheet.

8. After students complete their research, provide time for them to present their findings to the class.

9. Use student presentations as an opportunity to relate their investigations to the current news and debate about sea level rise and global climate change.

STUDENT WORKSHEET – LEVEL 5

DESIGN YOUR OWN INVESTIGATION

Develop Your Question:

_____

_____

_____

_____

Make a Plan: Make a list below of the specific data you will need to answer the question.

Location (station name)	Water Quality Parameter	Range of Dates	Notes

Other than the data listed above, what other information (if any) will you need to answer your question?

_____

_____

Get the data: Use the website to download the data you will need.

Interpret the data: What does your data show? Be specific and descriptive.

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Draw a Conclusion: What is the answer to your question? Use evidence and data to support your conclusion.

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