Hurricanes, Oysters, and Salinity

Materials

For the leader:

Computer

Projector

Graphing paper

For the activity:

Graphing paper or graphing program

2010-11 Oyster Mortality Data Tables

2010-11 Rainfall & Salinity Figures

2010-12 Rainfall & Salinity Figures

2010-12 Oyster Mortality Figures

Overview

Hurricane Irene made its first landfall in St. Croix on August 20th. Irene again made landfall on the Outer Banks of North Carolina on August 27th and in the Little Egg Inlet in southeastern New Jersey on August 28th. Throughout its path, Irene caused widespread destruction. Shortly after Hurricane Irene, Tropical Storm Lee hit the gulf coast and eastern seaboard (making its first landfall on September 2nd in Louisiana and impacting the mid-Atlantic area on September 5th). Due to Lee's large size and its slow forward movement, heavy rainfall was associated with the storm. In fact, the heavy rainfall resulted in historic flooding in the mid-Atlantic region.

In 2012, Hurricane Sandy became the second-costliest hurricane in United States history. While Sandy was only a Category 2 storm off the coast of the Northeast, it was the largest Atlantic hurricane on record (as measured by diameter, with winds spanning 1,100 miles (1,800 km)). In the early hours of October 29th, Sandy curved north-northwest and moved ashore near Brigantine, NJ. Hurricane Sandy affected 24 states, including the entire eastern seaboard from Florida to Maine and west across the Appalachian Mountains to Michigan and Wisconsin, with particularly severe damage in New Jersey and New York.

One of the major impacts of hurricanes on estuaries/bays is a change in the physical properties of the water. For example, more saline water can enter a bay if there is a high oceanic storm surge associated with the hurricane (often a short-term impact). Or large rainfall in the watershed during a hurricane can drop the salinity of the estuary (a short- to long-term impact). While estuarine organisms have evolved to live in a habitat with constant fluxes of the physical properties of the environment, every organism has physiological limits.

The Eastern oyster (*Crassostrea virginica*) is an important species both ecologically and economically. Ecologically, oysters create habitat and filter water. Economically, eastern oysters is an important fishery along the Atlantic coast of the United States, in 2010 an estimated 18.2 million pounds of meat was landed worth $76.2 million dollars. However, a trade-off exists for where oysters can live in estuaries/bays. In higher salinity environments, oysters experience faster growth but reduced survival due to disease and predation, whereas in lower salinity habitats, oysters grow more slowly, but disease and predation pressure is lower. Salinity is a primary factor limiting oyster distributions within estuaries. Oysters can tolerate a wide range of salinity allowing them to live in most regions of estuaries. Additionally, oysters can withstand periods of unfavorable conditions (e.g., exposure during low tide or episodic fresh water) by closing their shells and shifting to anaerobic metabolism. But, that means they are also unable to flush out toxic metabolites and constrained by the amount of energy resources available to sustain glycolysis and to maintain muscular closure of the shells.

Motivating Questions:
- **What is the relationship between salinity and oyster survival?**
- **How can hurricanes impact oysters and other marine organisms?**

Take Home Message
While oysters have evolved to live in a variety of environmental conditions, which are found in an estuary, there are limits to their physiological flexibility. When exposed to extreme conditions for too long, which can happen during hurricanes, they are not longer able to survive. However, not every storm results in oyster deaths.

Structure
The students will be exposed to a range of data relating to oyster health in the Delaware Bay. The students will observe, plot, and interpret rainfall, salinity, and oyster mortality data from 2010-2012. The lesson is cyclical so the students build upon prior knowledge of the system and their skills in interpreting the data sources to discover the story.

Time Required
60 minutes

Activity Outline
Engage: Students make observations about the rainfall and salinity in 2010 and 2011 to find Hurricane Irene and Tropical Storm Lee. They make predictions about what impacts the storms may have on oysters.	15 minutes
Explore: Students plot and interpret oyster mortality data from three stations in Delaware Bay from 2010 and 2011 to determine the impacts of Hurricane Irene and Tropical Storm Lee on the oyster population. Student then will apply their understanding of the relationship between salinity and oyster mortality to make predictions about the impacts of Hurricane Sandy (2012) and interpret the data from 2012.	35 minutes
Make Sense: Students synthesize what they have learned to think about how hurricanes impact oysters and other marine organisms	10 minutes
Total:	**50 minutes**

Audience
High school students (9^{th}-12^{th} grade).

Next Generation Science Standards
Performance & Expectation	Science & Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts

Earth Systems **HS-ESS-2**	Analyzing and interpreting Data	**ESS2.D** Weather and Climate	Stability and Change
Engineering Design, **HS-ETS1-1**	Asking Questions and Defining Problems	**ETS1.A**- Defining and Delimiting Engineering Problems	Influence of Science, Engineering, and Technology on Society and the Natural World
Earth's Systems, **HS-ESS2-5**	Planning and Carrying out Investigations	**ESS2.D**- Weather and Climate	Structure and Function

New Jersey State Science Standards

Grade	Content Statement	CPI#
12	Stability in an ecosystem can be disrupted by natural or human interactions.	5.3.12.C.2
12	Natural and human activities impact the cycling of matter and the flow of energy through ecosystems.	5.4.12.G.4
12	Science involves practicing productive social interactions with peers, such as partner talk, whole-group discussions, and small-group work.	5.1.12.D.1
12	Empirical evidence is used to construct and defend arguments.	5.1.12.B.3
12	Scientific reasoning is used to evaluate and interpret data patterns and scientific concepts.	5.1.12.B.4

Preparation (20 minutes)

1. Write the motivating questions up on the board:

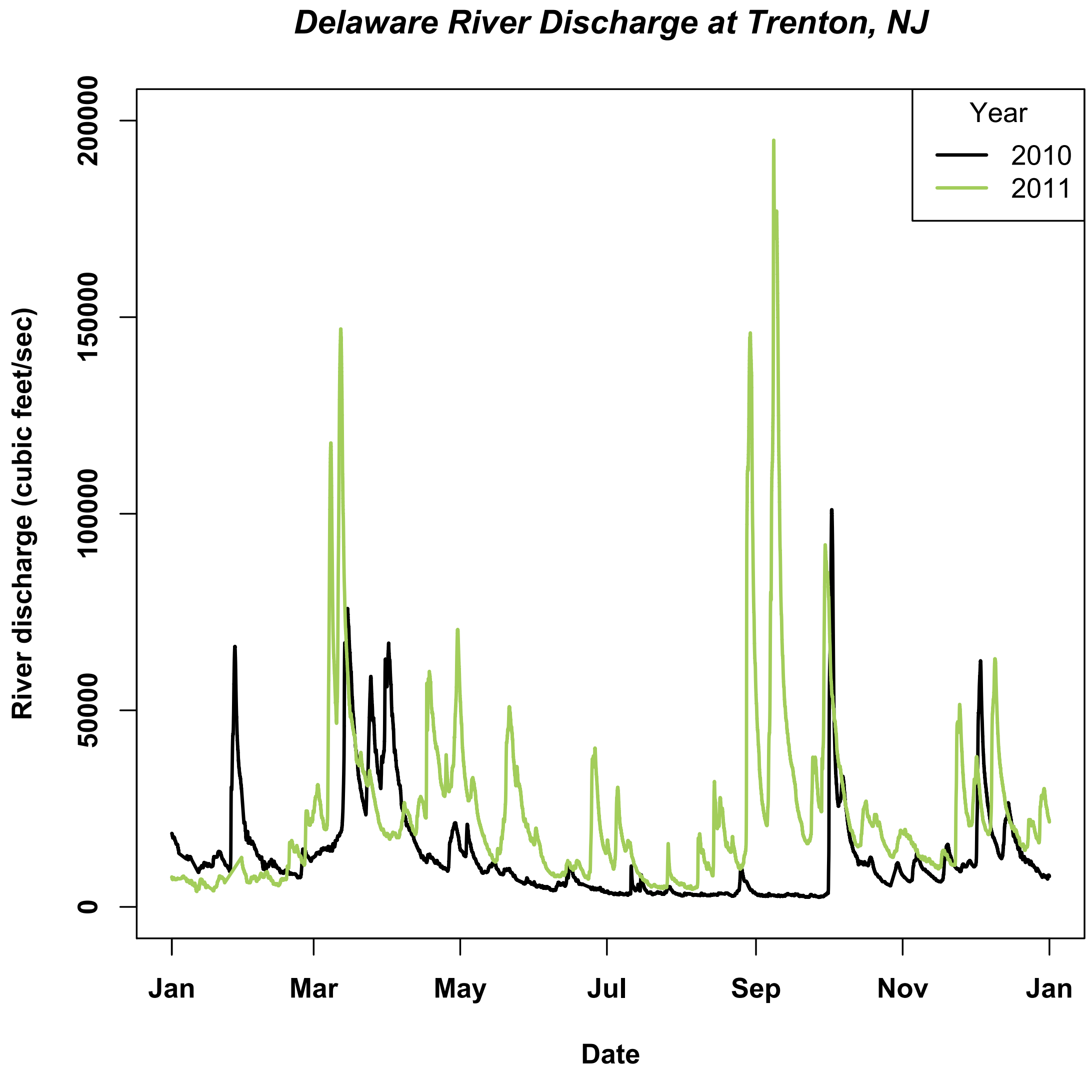
   Q. What is the relationship between salinity and oyster survival?
   Q. How can hurricanes impact oysters and other marine organisms?

2. Make sure you have enough copies of the figures to pass out to each table group: 2010-11 River Discharge, 2010-11 Salinity, 2010-12 River Discharge, 2010-12 Salinity, 2010-12 Hope Creek Oyster Mortality, 2010-12 Shell Rock Oyster Mortality, and 2010-12 New Bed Oyster Mortality.
3. Make sure you have enough copies of the data tables for each group to get a data table. Remember that not all groups will plot all of the data, but rather each group will plot data from one station and they will jigsaw their knowledge together with other groups to look for Bay-wide patterns.
4. Make sure you can project the Delaware Bay map of oyster beds.

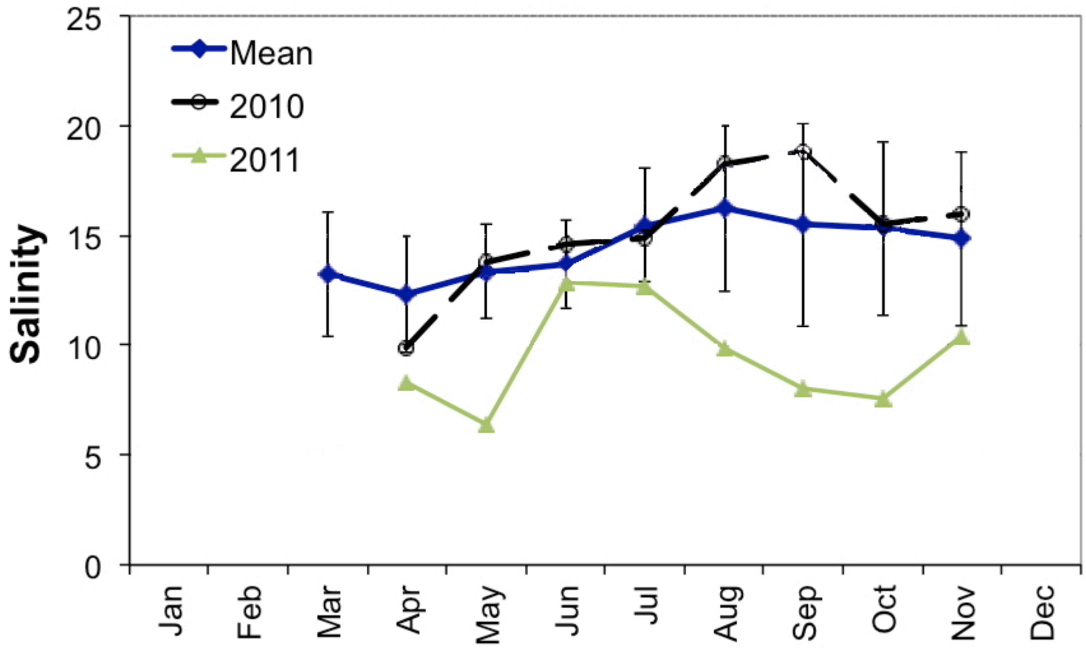
Engage (15 minutes)

1. As the students come into class have the "Delaware River Discharge at Trenton, NJ" and "2010-2011 Salinity" figures laid out of their tables. Invite the students to look at the figures in their small groups and work together to understand that data visualizations, draw conclusions from the data visualizations, and determine what the data visualizations are telling us about rainfall

and salinity conditions in 2010 and 2011 in the Delaware Bay area. Note, river discharge is a proxy



for rainfall.

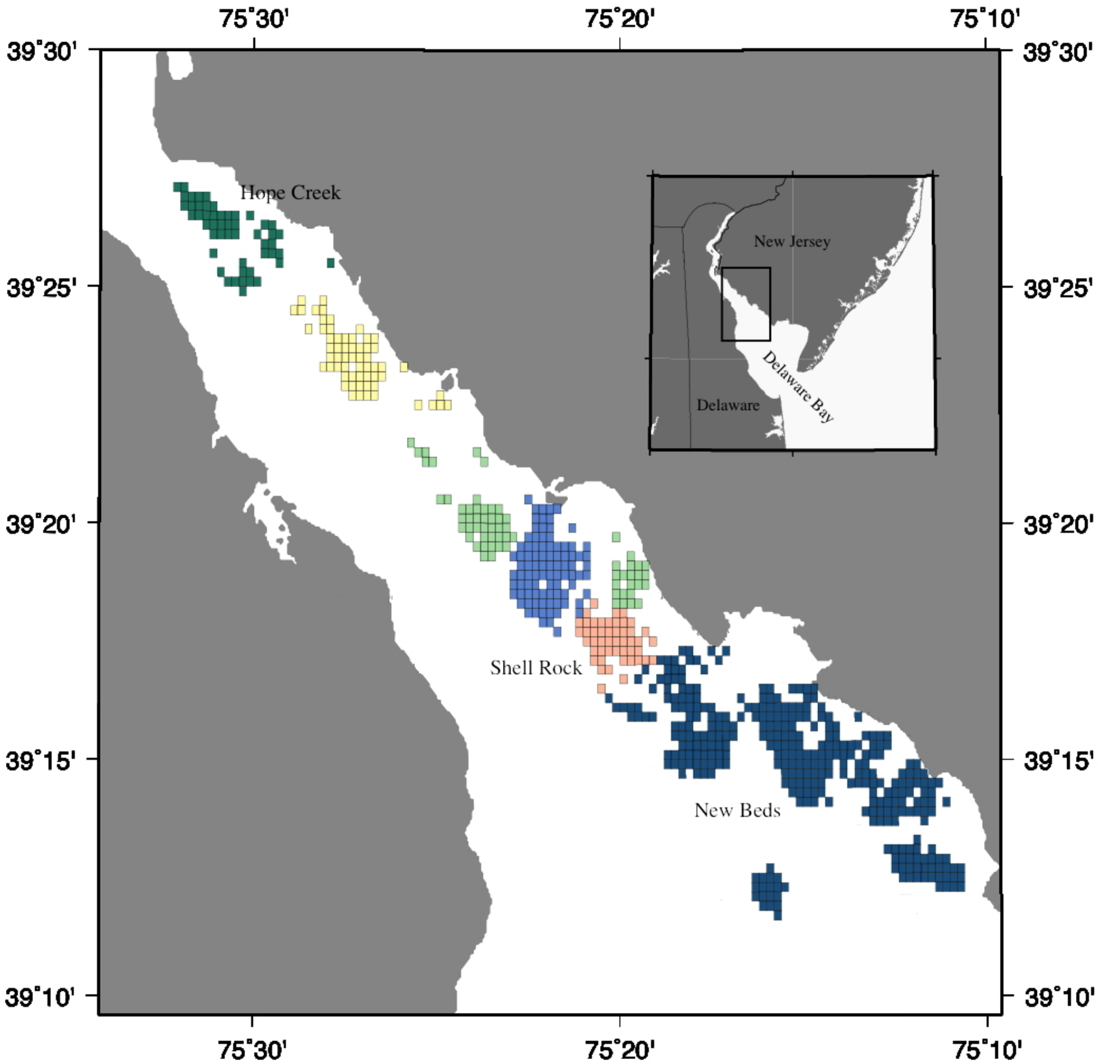


2. Give the students about 3 minutes to initially explore the graphs in their small groups. As the conversations slow down, point the students towards the questions on the board:
    a. What were water conditions like in 2010? Were the water conditions similar or different in 2011?
    b. Did any large events happen, as seen by a large or unexpected change in the data, in 2010? In 2011?
3. Then pull the students back together as a class and have the students share with one another what they found. As the students are presenting be accepting of all answers and remind students to state what evidence they used to draw their conclusions. Make sure the students understand the general patterns in the data and know the following information.
    a. 2010 was a relatively typical year (salinity data aligns well with the 14-year mean salinity and falls within the variation, error bars, around the mean). There were a few spikes in river discharge due to snow and rainstorms.
    b. 2011 was a low salinity year (salinity data below the mean and mostly far below the observed variation) due to multiple large influxes of water into the system (high spikes in river discharge data).
    c. Around mid-March and early-September in 2011 there were two large precipitation events in the Delaware Bay area. The mid-March spikes are from snowstorms and snowmelt. The early September spikes are from Hurricane Irene and Tropical Storm Lee. In fact 50% of the total 2011 precipitation feel in the weeks surrounding Hurricane Irene (August 28, 2011) and Tropical Storm Lee (September 5, 2011).
4. Point to the motivating question: How can hurricanes impact oysters and other marine organisms? Have the students think about this question for a minute and then turn to their partner and share their initial predictions and thoughts.

Explore (35 minutes)

Students plot and interpret oyster mortality data from three stations in Delaware Bay from 2010 and 2011 to determine the impacts of Hurricane Irene and Tropical Storm Lee on the oyster population. Student then will apply their understanding of the relationship between salinity and oyster mortality to make predictions about the impacts of Hurricane Sandy (2012) and interpret the data from 2012.

1. After the students have shared with one another ask for a few volunteers to report out what the partner groups were discussing about the impacts of hurricanes on marine organisms. Be accepting of all answers and encourage students to state what evidence or previous knowledge they used to come up with their predictions.
2. Ask the students (in a popcorn style) what kinds of data would we need to look at to determine if there was an impact of Hurricane Irene and Tropical Storm Lee on oysters in the Delaware Bay.
3. After a few suggestions or you feel that the conversation is slowing down, provide the students with some background information about oysters:
    a. Oysters create habitat through oyster beds (oyster larvae only settle on other oysters) and filters particles out of the water for food, which cleans the water for other marine organisms.
    b. Oysters can tolerate a wide-range of salinity and withstand periods of unfavorable conditions, which is necessary living along the shores of tidal estuaries.
    c. During unfavorable conditions, oysters close their shells and shift to anaerobic metabolism in order to survive. However, oysters are unable to flush out toxic metabolites when their shells are closed. In addition, oysters are constrained by their energy stores, or resources, that are required for maintained function of their systems and to keep their shells closed.
    d. There is also a tradeoff for where oysters live. When oysters live in higher salinity areas, oysters are able to grow faster but there is an increase in the death from disease and predation. However, when oysters live in lower salinity areas the prevalence of disease and predation is decreased but oysters also grow more slowly.
    e. In the Delaware Bay are the annual natural mortality of oysters is <5 – 55% per year.
4. Explain to the students that they will be graphing the oyster mortality from 2010 and 2011 from three different stations along the Delaware Bay. The students will work in small groups to plot and interpret the data; therefore not every group will have the same data. It may be helpful to display the "Delaware Bay Oyster Stations" map as you are explaining where the data came from.



5. Provide the different groups with the appropriate Data Tables and graphing paper. Make sure your students know to plot the dates (by Month) along the x-axis, the box frequency (oyster mortality) along the y-axis, and to plot 2010 and 2011 as separate lines on the graph.

Hope Creek % Total Oyster Mortality

	2010	2011
March		
April	10.7%	15.5%
May	14.5%	20.5%
June	15.9%	16.2%
July	12.1%	18.7%
August	10.0%	11.0%
September	5.1%	23.4%
October	10.2%	67.0%
November	9.3%	62.8%

Shell Rock % Total Oyster Mortality

	2010	2011
March		
April	22.0%	13.9%
May	21.3%	13.4%
June	14.7%	11.0%
July	11.5%	5.0%
August	12.5%	9.4%
September	12.5%	8.8%
October	15.4%	11.6%
November	13.3%	11.1%

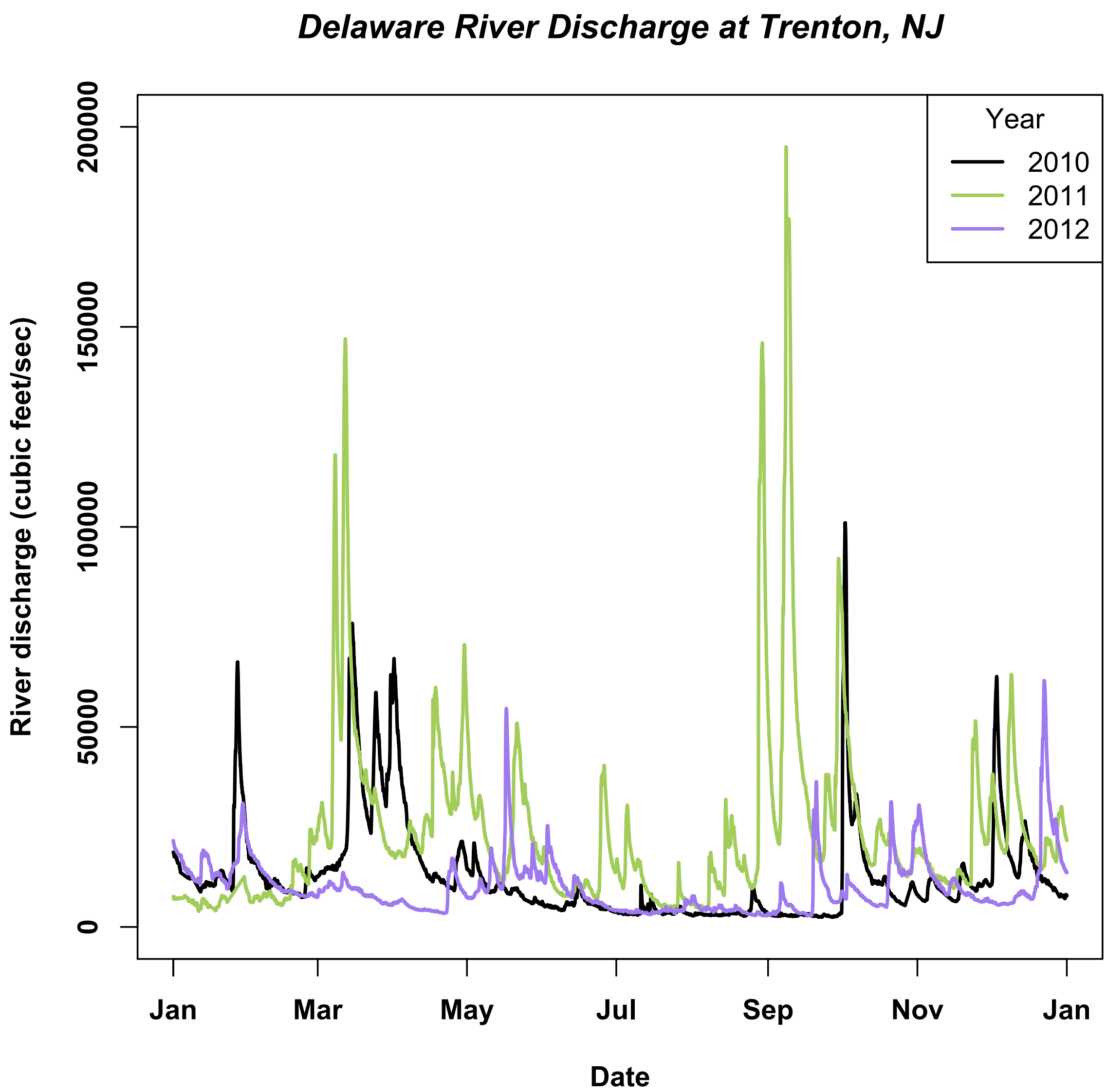
New Bed % Total Oyster Mortality

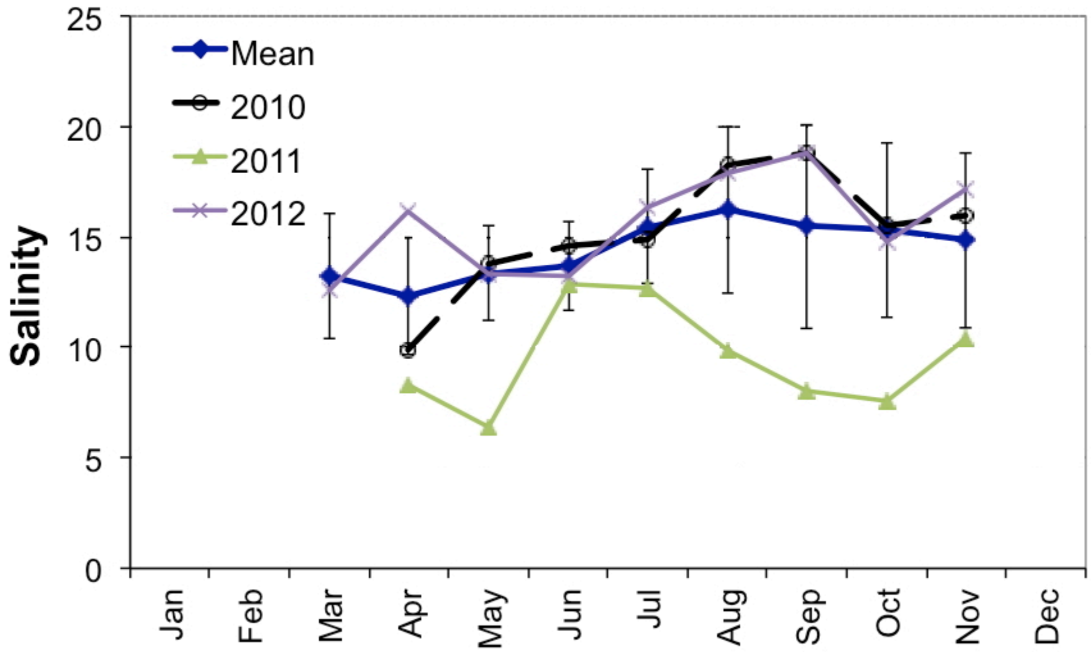
	2010	2011
March		
April	16.3%	39.1%
May	26.0%	27.2%
June	41.8%	37.1%
July	35.5%	24.2%
August	26.0%	21.5%
September	48.1%	15.0%
October	34.1%	18.0%
November	34.0%	8.9%

6. Provide the students with enough time to plot the data and interpret the results (the data figures are included at the end of this write up).
7. When the students have plotted and interpreted their data, have them connect with two other groups so that each larger group has Hope Creek, Shell Rock, and New Bed data figures. Have the students present to one another what their data shows about oyster mortality in their region of the Delaware Bay.
8. The students should work together to develop an understanding of the impact of Hurricane Irene and Tropical Storm Lee on oysters in Delaware Bay.
9. After a few minutes bring the students back together as a class to discuss what patterns the students observed with respect to hurricanes and oyster mortality.
    a. Note – the students should observe that oyster mortality increased significantly at Hope Creek in 2011 and decreased considerably at New Bed in 2011 from 2010. These increases and decreases coincide with the monitoring collections after Hurricane Irene and Tropical Storm Lee (September, October, November).
10. As the students are discussing their opinions, point to the motivating question of:

    Q. What is the relationship between salinity and oyster survival?

    a. Note – the students should be able to articulate that the long period of low salinity due to Hurricane Irene and Tropical Storm Lee is correlated with a significant increase in oyster mortality in the upper bay areas (Hope Creek, due to physiological constraints).
11. When the conversation slows down, ask the students what impacts they predict Hurricane Sandy had on the oyster population in the Delaware Bay, knowing what they now know about hurricanes, oysters, and salinity. Allow the students to think to themselves, before turning to a neighbor to discuss their predictions.
12. After a minute or so, have the class come back together and share out what they were talking about with their partners. Write a few of the predictions on the board.
13. Pass out the 2010-2011 River Discharge, Salinity, and Oyster Mortality graphs out to the small groups. Have the students look through the data to determine what the impact of Hurricane Sandy was on oysters in Delaware Bay.


Delaware River Discharge at Trenton, NJ
River discharge (cubic feet/sec)
0
50000
100000
150000
200000
Year
2010
2011
2012
Jan
Mar
May
Jul
Sep
Nov
Jan
Date



Make Sense (10 minutes)

1. After the students have come to consensus on how to interpret the figures bring the class back together and lead a discussion with the students about what they found.
    a. Note – the students should have observed that Hurricane Sandy did not result in a lot of river discharge (rainfall) and thus 2012 was a typical salinity year (even around Hurricane Sandy). Therefore the salinity conditions were average for the oyster populations in Delaware Bay. The mortality of oysters in the fall in Delaware Bay in 2012 was similar to 2010, with higher mortality at the lower bay site, New Bed (this is due to disease and predation), and less mortality at the upper bay site, Hope Creek.
    b. Note – students may wonder why the oyster mortality decreased at Hope Creek throughout 2012, this is the residual result of the dye off from Hurricane Irene and Tropical Storm Lee. The important piece is that the mortality did not increase following Hurricane Sandy, but rather continued to decline towards 2010 levels.
2. Once the discussion slows down, point to the motivating questions and ask:
   Q. What is the relationship between salinity and oyster survival?
   Q. How can hurricanes impact oysters and other marine organisms?
1. Ask students to share their ideas about the questions with a partner. After a minute, ask volunteers to share the ideas they discussed with the entire class. Be accepting of all responses from the students. This is your opportunity to make sure the students understand the "take home message" of the section.
2. Ask if the students have any final questions about the activities and presentations of the day.

Hurricanes, Oysters, and Salinity – Data Tables & Figures 2010-11

Hope Creek % Total Oyster Mortality

	2010	2011
March		
April	10.7%	15.5%
May	14.5%	20.5%
June	15.9%	16.2%
July	12.1%	18.7%
August	10.0%	11.0%
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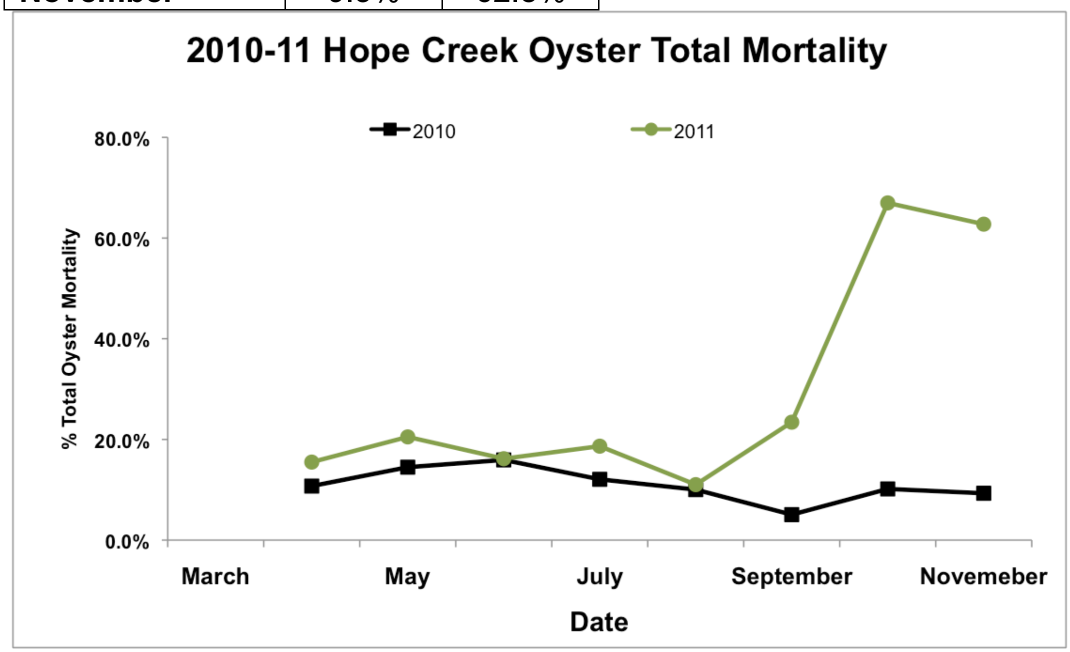

Shell Rock % Total Oyster Mortality

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April	22.0%	13.9%
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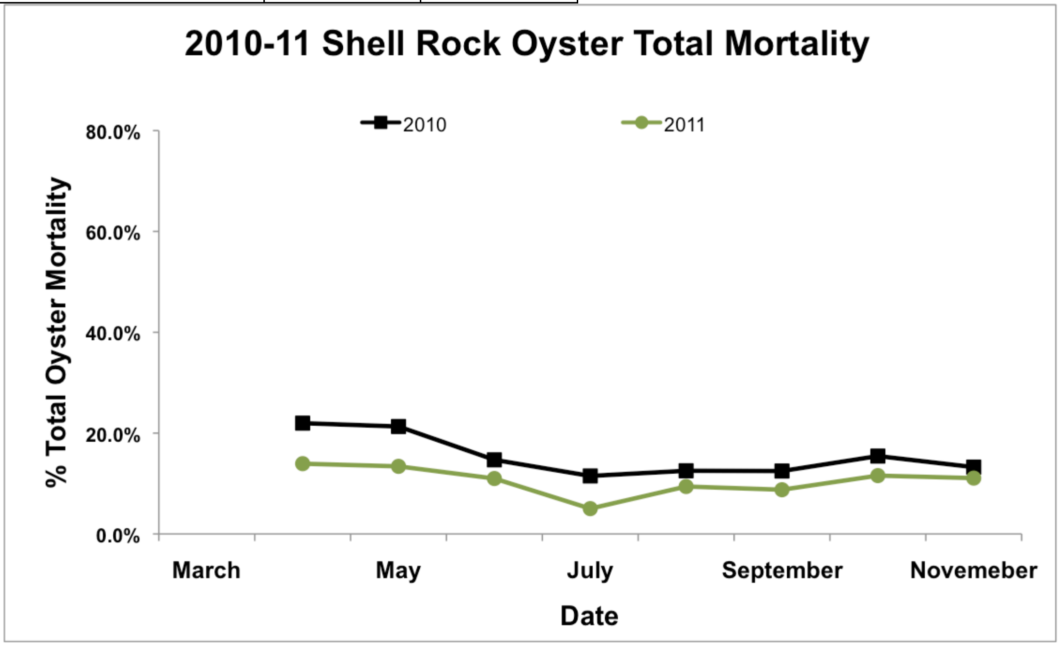
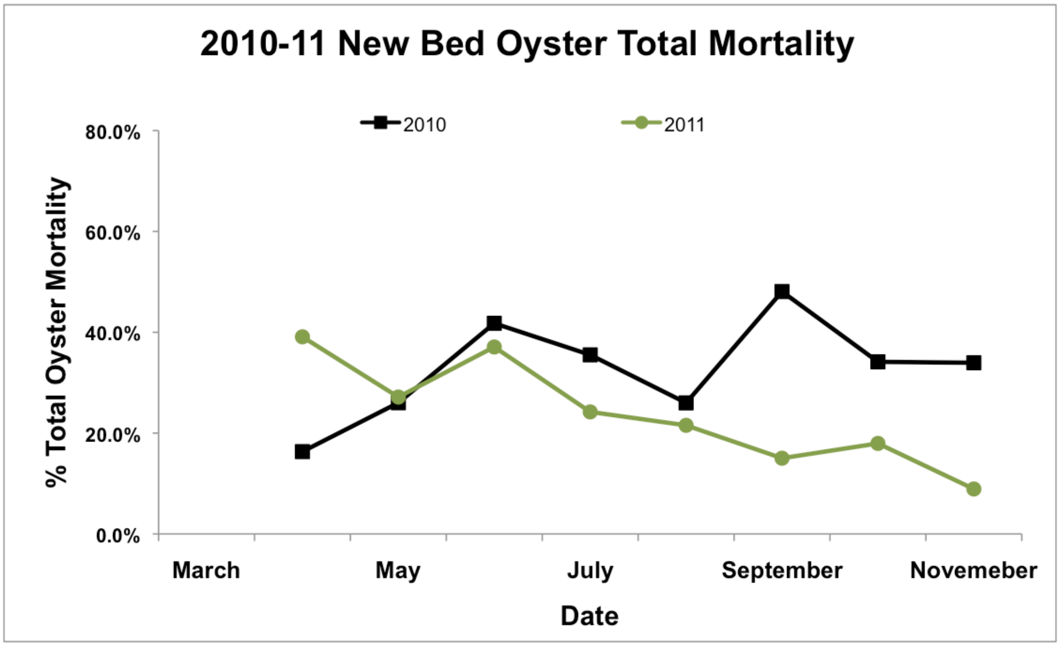
July	11.5%	5.0%
August	12.5%	9.4%
September	12.5%	8.8%
October	15.4%	11.6%

November	13.3%	11.1%

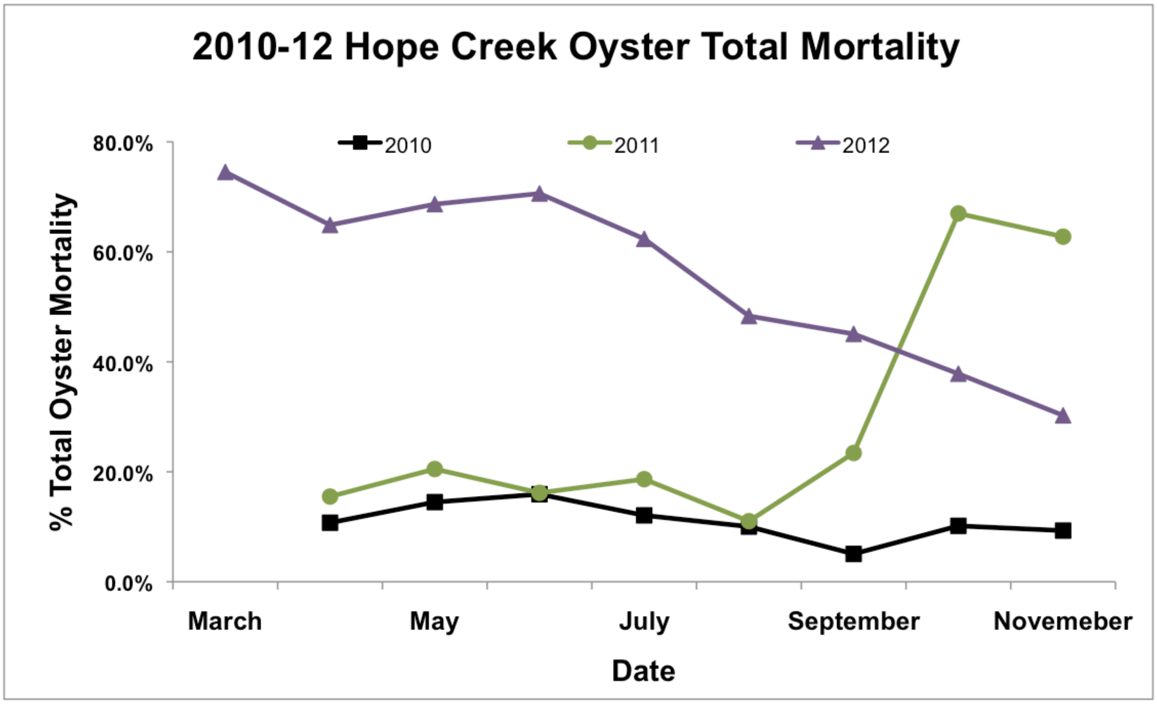


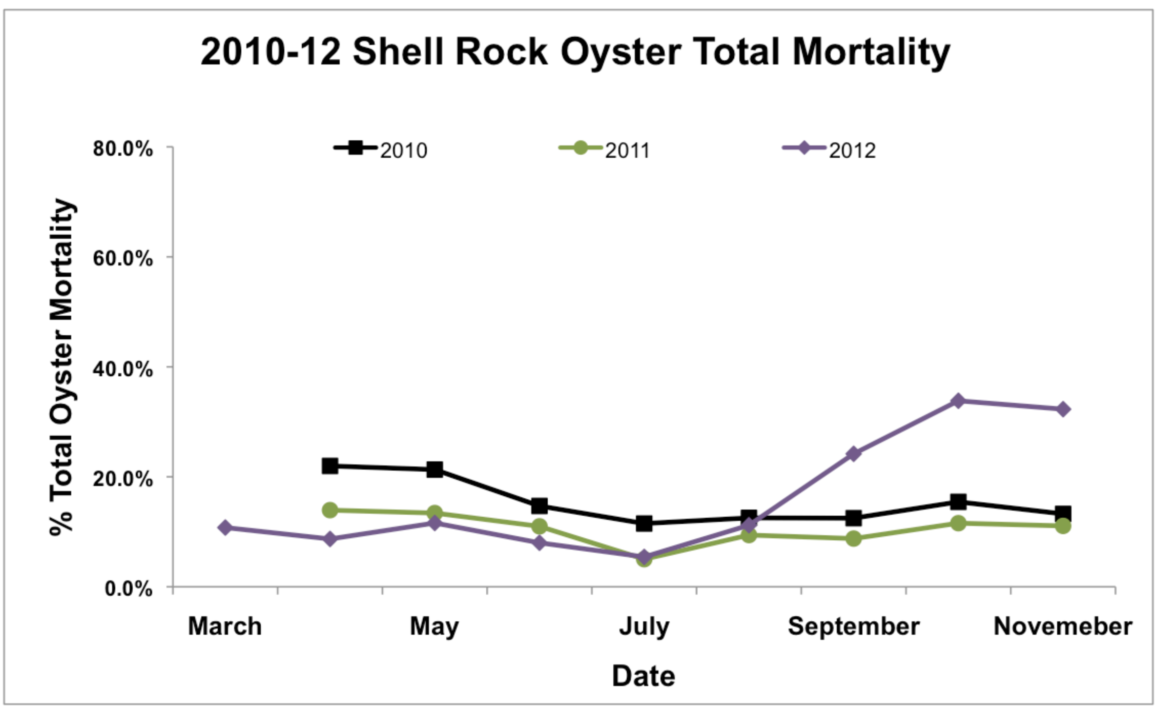
New Bed % Total Oyster Mortality

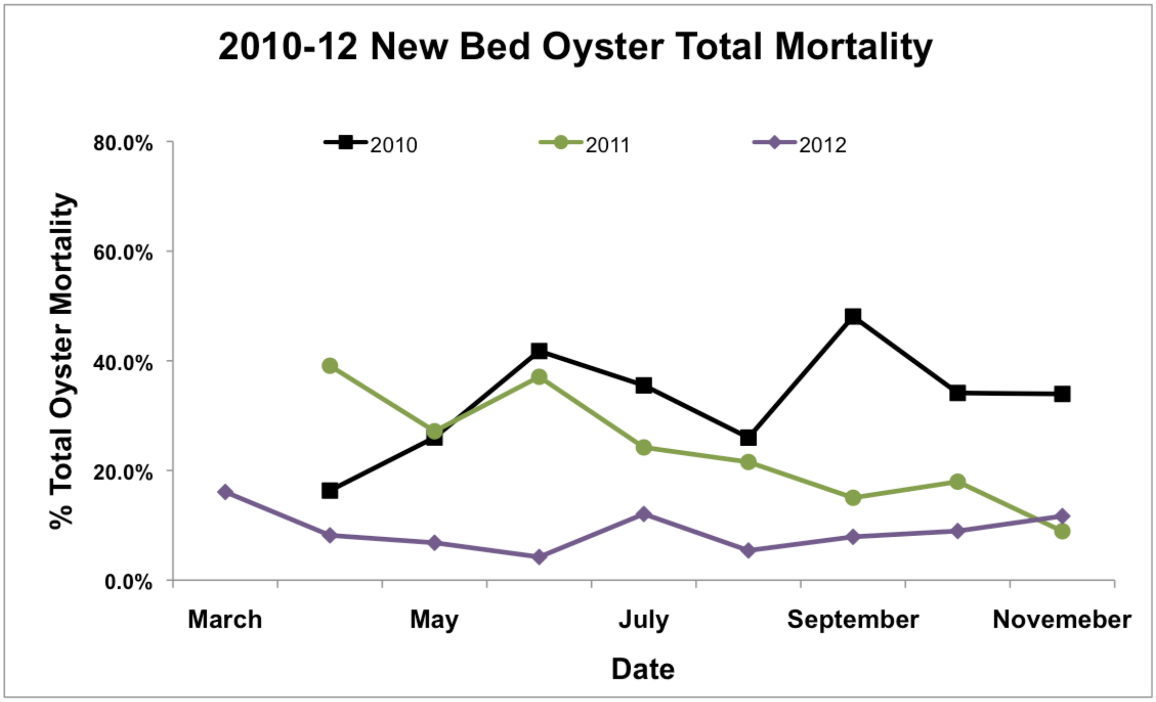
	2010	2011
March		
April	16.3%	39.1%
May	26.0%	27.2%
June	41.8%	37.1%
July	35.5%	24.2%
August	26.0%	21.5%
September	48.1%	15.0%
October	34.1%	18.0%
November	34.0%	8.9%


2010-11 New Bed Oyster Total Mortality
2010
2011
% Total Oyster Mortality
80.0%
60.0%
40.0%
20.0%
0.0%
March
May
July
September
Novemeber
Date

Hurricanes, Oysters, and Salinity – Data Figures 2010-12






2010-12 New Bed Oyster Total Mortality
2010
2011
2012
% Total Oyster Mortality
80.0%
60.0%
40.0%
20.0%
0.0%
March
May
July
September
Novemeber
Date