APPENDIX B: Student Pages

ACTIVITY I: Biotic and Abiotic Conditions Affecting the Eastern Oyster – Oyster Habitat Requirement Concept Map

ACTIVITY II: The Oyster Life Cycle

ACTIVITY III: Oyster Habitat Requirements Data Table

ACTIVITY IV: Applying Data to Make Decisions about Oyster Restoration – Modifying Your Oyster Habitat Requirement Concept Map

ACTIVITY V: Applying Data to Make Decisions about Oyster Restoration – Oyster Decision Support Tool (ODST)

ACTIVITY VI: Communicating Your Proposed Oyster Sanctuary Management Plan

EXTENSION: Evaluating an Oyster Sanctuary Plan for Harris Creek

ACTIVITY I: Biotic and Abiotic Conditions Affecting the Eastern Oyster: Oyster Concept Map

STUDENT PAGE

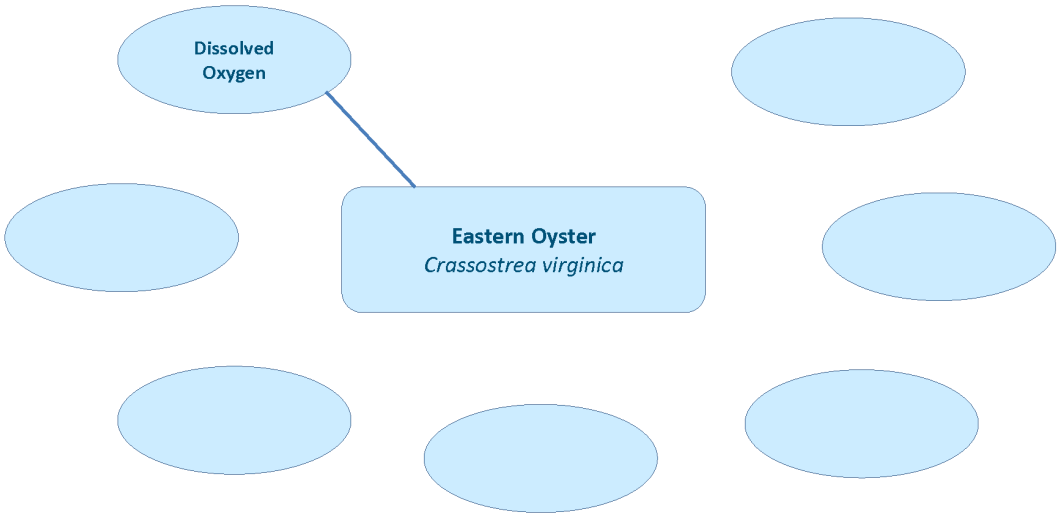
What do oysters need to survive?

Working in small groups, create a concept map (feel free to use the template below), and add as many ovals as you need, illustrating what your group thinks oysters need to survive.

What are the habitat parameters you think are important to study?

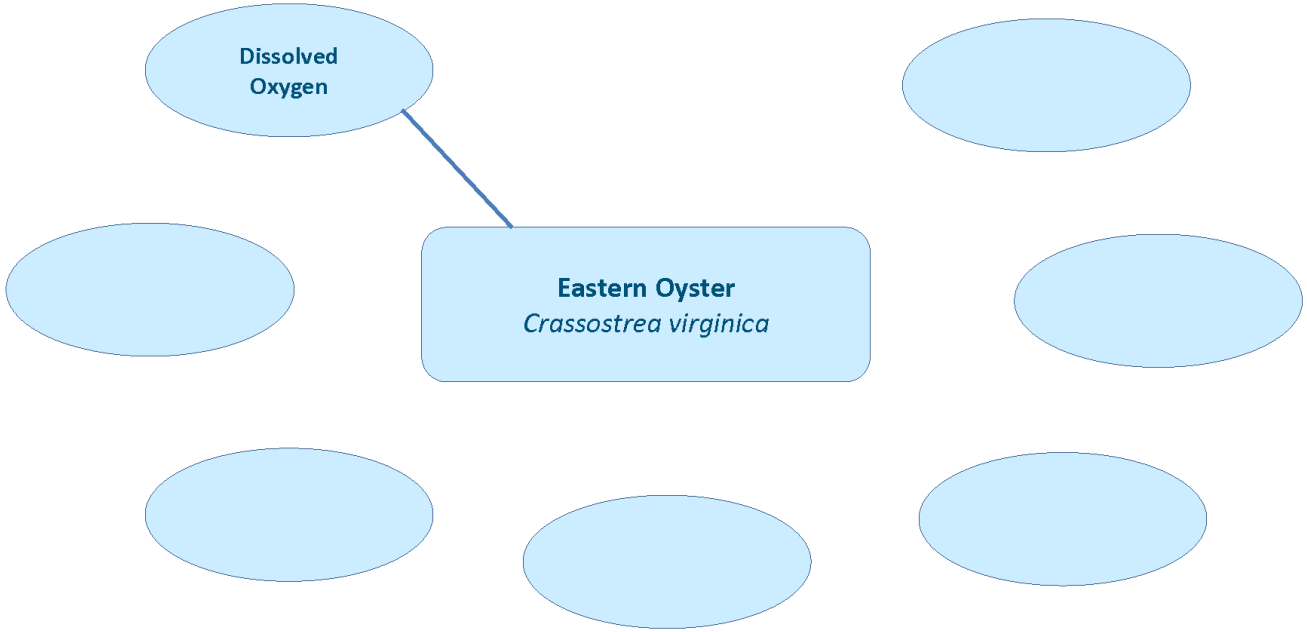
Use lines to connect each of these parameters with the oyster. Be as specific as possible (e.g., what kind of food do oysters need?) Do any of these parameters interact with one another? Explain.

Oyster Habitat Requirement Concept Map



A larger working version can be found on the next page. Feel free to add more circles to describe habitat criteria.

Oyster Habitat Requirement Concept Map



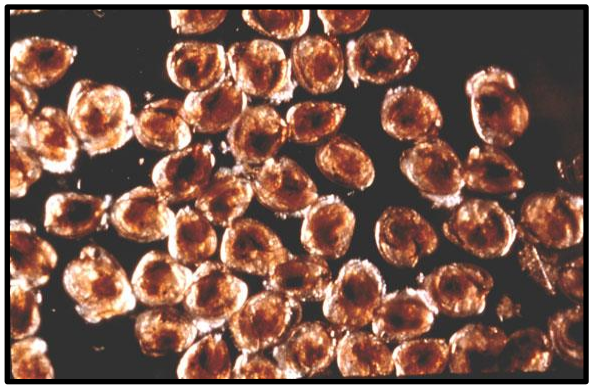
ACTIVITY II: The Oyster Life Cycle
STUDENT PAGE

The following background information is being used with permission from the University of Maryland Horn Point Oyster Hatchery website, courtesy of Dr. Don "Mutt" Meritt, http://hatchery.hpl.umces.edu/oysters/oysters-life-cycle/

The Oyster Life Cycle Background Information

Adult oysters reach their reproductive prime at about 3 years of age. In order for an oyster to spawn, they must eat naturally occurring phytoplankton in the water column and use that energy and invest it into creating a gonad, which will be either eggs or sperm. An oyster uses environmental cues to begin the ripening process in the early spring. An increase in water temperature, coupled with an increase/decrease in salinity or a change in the phytoplankton biomass usually stimulates the oyster to begin putting on gonad. This process can take up to months in the spring.

Once adult oysters are ripe they can begin to spawn. Environmental cues fuel the spawning process with oysters preferring to spawn at water temperatures between 20°C to 30°C (74°F to 86°F) and at salinity above 10ppt. It only takes one oyster to release its gonad to encourage other oysters to commence spawning. For example, if a male oyster starts to spawn by releasing his gonad into the water column, the oysters surrounding him will filter in some of this sperm. Once the other oysters detect the presence of sperm in the water, they will begin to release their own gonad to ensure successful reproduction. Fertilized eggs cannot exist without both egg and sperm. The eggs and sperm will encounter each other in the water, begin the fertilization process, and drift away from the spawning grounds in the water currents.



Fertilized eggs drift in the water column undergoing cell division until they become juvenile larvae. Oyster larvae will live in the water column for the next two weeks maturing through different stages. Larvae swim in the water currents in order to follow the phytoplankton, their source of food. Larvae are not capable of swimming horizontally, but they can move vertically to some extent. Once the larvae are approximately two weeks old and in the *pediveliger* stage (larva with a foot), they begin to

concentrate at the bottom of the river system to search for a hard substrate. The larvae utilize an appendage that they grow called a foot. This foot helps them crawl around on the bottom to find a suitable substrate for them to attach to. Once they have successfully located a suitable location, usually an oyster shell, they begin to attach to the shell by secreting a glue-like substance. The larvae then undergo a complete metamorphosis of internal anatomy and become what we call a spat.

The oyster spat will start to feed and put all of their energy into shell growth by secreting calcium carbonate from the water column. The oyster becomes a juvenile at one year of age, and officially becomes an adult at year three. Oysters typically grow up to an inch per year. This is dependent on salinity and the quality of the water column. In higher salinity areas, oyster will grow faster than in lower salinity areas.

In Maryland, legal harvest size is three inches or approximately three years of age. The adult oysters can be harvested for market at this time. The oysters on the reef will continue to filter the water column, provide habitat, and reproduce contributing to the ecological benefits to the Bay until they are harvested.

If computers and Internet access are available, feel free to use the following links:

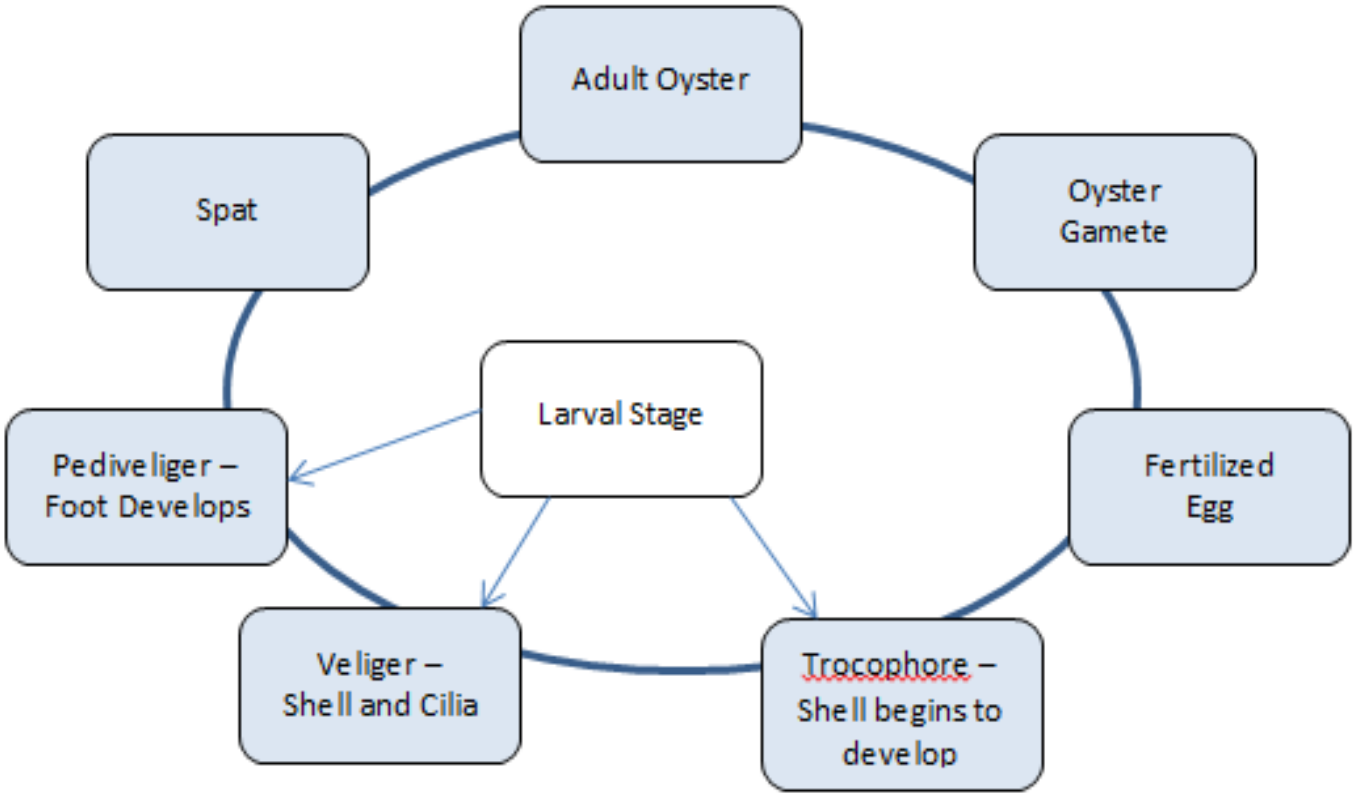
University of Maryland Horn Point Oyster Hatchery
http://hatchery.hpl.umces.edu/oysters/oysters-life-cycle/

Chesapeake Bay Program,
http://chesapeakebay.noaa.gov/fish-facts/oysters
(View the oyster life history and habitat section).

What do oysters need to survive throughout their multiple life stages?

Now that you have learned more about oysters and their various life stages, use the Oyster Life Cycle Habitat Requirements Concept Map template on the following page to illustrate how oyster habitat requirements may change depending on the life stage. This concept map will be used again to illustrate additional interactions between oysters, and other environmental and human factors.

Habitat Requirements Concept Map for the Oyster Life Cycle



ACTIVITY III: Oyster Habitat Requirements Data Table

STUDENT PAGE

Because of the oyster's importance in the Chesapeake Bay, a great deal of scientific research has been done to better understand them, and much is still going on today. Some of this research has looked at how water quality and other factors impact oyster survival and reproduction. In this section you will be using excerpts from Habitat Requirements for Chesapeake Bay Living Resources, (1991 Revised Edition). This resource documents the water quality and other habitat requirements for numerous Bay species. You will be using the section on oysters to learn more about their specific needs throughout their life cycle.

PROCEDURE

1. Your teacher will provide you with the *Oyster Chapter* from Habitat Requirements for Chesapeake Bay Living Resources.
2. Closely read the *Introduction, Background, and Ecological Role* sections of this chapter (be sure to highlight or take notes on important passages in these sections).
3. In your small groups identify who is to become an expert on the following aspects of oyster habitat:
    a. Water Temperature
    b. Salinity
    c. Dissolved Oxygen
    d. pH
    e. Structural Habitat (substrate and depth)
4. Use the information you gathered to complete the *Habitat Requirements Data Table* (see Table on *Page 10*) to modify and further develop the *Oyster Habitat Requirement Concept Maps* for the Eastern oyster, including the *Life Cycle Concept Map* template on *page 7*. Be specific about the oyster habitat requirements at each life stage, and identify factors that may impact the abiotic conditions described in the habitat requirements. These factors could have both positive and/or negative impacts on the oyster (e.g., runoff, climate change, etc.). Use the following resources and learning experiences as you develop the model/concept map.
    a. *Habitat Requirements for the Eastern Oyster* chapter – Focus on the introductions and special problems sections.
    b. Chesapeake Bay Program – Restoring Oyster Reefs
    http://www.chesapeakebay.net/indicators/indicator/restoring_oyster_reefs
    Click on MAPS to view restoration sites in Maryland and Virginia
    c. Fish Banks Simulation – Experience and lessons learned (Module 2)

d. Oyster Sanctuaries, MD Department of Natural Resources
http://dnr2.maryland.gov/fisheries/Pages/oysters/sanctuaries.aspx

e. Oyster Disease: Virginia Institute of Marine Science,
http://www.vims.edu/research/departments/eaah/programs/molluscan_health/Research/shellfish_diseases/index.php **OR**

Chesapeake Bay Oyster Diseases and Background & 2011 Status Presentation,
https://drive.google.com/open?id=0B-1W5S46ODQNM2V3ZDQzWGQ5SkU
(Chris Dungan, MD Department of Natural Resources)

5. Be prepared to present and discuss your completed oyster habitat model/concept map. In particular, consider how your model could be used to identify locations targeted for oyster restoration in Chesapeake Bay.

ACTIVITY III: Oyster Habitat Requirements Data Table

STUDENT PAGE

The group's experts should provide the information needed to complete the top of this table.

Parameters	**Oyster Habitat Requirements**										**Oyster Disease**	
	Eggs	Larvae	Spat	Young	Adults	Survival	Feeding	Growth	Gametogenesis	Spawning	MSX	Dermo
Oyster Bed Designation (sanctuary, commercial, etc.)												
Substrate (soft or hard bottom)												
Water Depth												
Water Temp. (°C)												
Salinity (ppt)												
DO (mg/L) (June-August)												
pH												

Other Considerations	**Site 1:**	**Site 2:**	**Site 3:**	**Site 4:**
Management Boundary/ Oyster Bed Designation (sanctuary, reserve, commercial bar, etc.)				
Disease Presence				
Live Oyster Density (#/m^2)				
Other:				

Oyster Habitat Requirements Data Activity Sheet

1. Choose a site within 1.5 miles of the Oxford Lab, where oysters would survive and successfully reproduce during June and July of _____. (Based on the data available, your teacher will select the year.
   (YEAR)

2. Review the chapter, *Eastern Oyster*, from *Habitat Requirements for Chesapeake Bay Living Resources*, (1991). pp. 3.1 – 3.14.

3. Fill in the habitat requirement chart. (Note: Some parameters will not be applicable for a particular life stage; e.g., substrate is not applicable for egg or larvae stages).

4. Using the Oyster Decision Tool, the maps and charts provided, and the completed table, identify site(s) that would have sustained successful oyster reproduction in June and July _____.
   (YEAR)

5. What is the latitude and longitude of the site you chose?

   _____

   (See lower right hand corner of Oyster Data Tool).

6. Answer the following questions:
   a. What habitat requirements and oyster life stages did you consider?

   b. What were the parameters used?

   c. Did you place your oyster in a commercial oyster bar or in a sanctuary? Why?

   d. How did oyster diseases influence your decision to place your oyster where you did?

e. Were there other sites that you considered? How did you decide to eliminate them as candidates?

g. Can you predict how the parameters may change for June and July _____?
(YEAR)

What data would you use to make your determination?

ACTIVITY IV: Applying Data to Make Decisions about Oyster Restoration – Modifying Your Oyster Habitat Requirement Concept Map

STUDENT PAGE

Thus far, you have collected data and evidence from secondary sources about the biotic and abiotic conditions that oysters need to survive and reproduce in Chesapeake Bay. Now, apply your knowledge of the oyster life cycle and habitat conditions that support survival within each life stage. This will help you as you apply what you have learned to make decisions regarding potential oyster restoration sites in the Chesapeake Bay.

1. Using the *Oyster Life Cycle Concept Model* and the *Habitat Requirements Data Table* modify and further develop your model (concept map) for the Eastern oyster. You could combine all of the information you need to create a concept map using a Web-based application, such as *Insight*, that is available through your school.

   Be specific about the oyster habitat requirements at each life stage, and identify factors that may impact the abiotic conditions described in the habitat requirements. These factors could have either positive or negative impacts on the oyster (e.g., runoff, climate change, etc.).

2. Use the following resources and experiences as they develop your concept map.

   - Oyster Habitat Requirements Chapter, and focus on the *Introduction* and *Special Problems* sections.
   - Chesapeake Bay Program – Oyster Restoration http://www.chesapeakebay.net/indicators/indicator/restoring_oyster_reefs
   - Fish Banks activity experience and lessons learned from *Module 2*
   - Oyster Sanctuaries: http://dnr2.maryland.gov/fisheries/Pages/oysters/sanctuaries.aspx
   - Oyster Disease
     - Virginia Institute of Marine Science http://www.vims.edu/research/departments/eaah/programs/molluscan_health/Research/shellfish_diseases/index.php
     - Maryland Department of Natural Resources, Chesapeake Bay Oyster Diseases, Background and 2011 Status Presentation (Chris Dungan, research scientist) https://drive.google.com/open?id=0B-1W5S46ODQNM2V3ZDQzWGQ5SkU

When complete, share your concept maps with the rest of the class, and discuss any unique components you included.

ACTIVITY IV: Applying Data to Make Decisions about Oyster Restoration – Using the NOAA Oyster Decision Support Tool (ODST)

STUDENT PAGE

In this activity you will utilize what you have learned about the oyster's habitat requirements and other important factors that influence oysters to identify a specific location to target oyster restoration. During this activity you will use the ***NOAA Oyster Decision Support Tool*** (ODST - http://science.ncbo.noaa.gov/odst/) or maps and other data provided to analyze available data and identify potential restoration locations.

About the Oyster Decision Support Tool (ODST)

https://chesapeakebay.noaa.gov/habitats-hot-topics/oyster-decision-support-tool-helps-visualize-habitat-restoration-data

The Oyster Decision Support Tool is a map-based way to access information on oysters, oyster habitat, and oyster restoration projects in the Chesapeake Bay. Data for the ODST came from state and federal agencies working in the Chesapeake, scientists, academic institutions, and nonprofits. The ODST includes information on the following:

- Maps and graphs of Maryland oyster disease, live oyster count, spatfall, and mortality levels at each oyster bar sampled, by year
- Dates of oyster-related activities on each bar in Maryland, and map layers showing where oyster restoration has occurred
- Maps and graphs of modeled water quality data (bottom salinity and temperature)
- Seafloor mapping in Maryland and Virginia (describing various bottom types such as shell, sand, and mud)
- Historic oyster reef boundaries ("Named" Oyster Bars in Maryland and Baylor Grounds in Virginia)
- Maryland oyster sanctuary and reserve boundaries

Using the Oyster Decision Support Tool

Like Google Earth, FieldScope and other GIS/Map resources, the ODST is a collection of data that you can visualize and ask questions about. Note that users have the ability to turn on and off many data layers within the ODST. In some layers you can even limit the data displayed further by choosing to view only specific components of the layer. In the case of the temperature and salinity layers, you can use the ODST to show only areas with a small range of temperature or salinity for any month with data. Additionally, when you click on the map the ODST will run a report for that location, which provides all the available data for

that location in the ODST. The ODST is a powerful GIS tool, and one of the best ways to learn about this tool is to simply use it. Below are some images from the tool with key features highlighted.

ODST Restoration Siting Procedure

1. In small groups, you will take on the role of an oyster management team charged with identifying a site for oyster restoration activities. Your teacher will describe the area to focus on for the restoration siting. Be sure to reference the oyster model/concept map and habitat requirements data table to evaluate potential restoration locations using the Oyster Decision Support tool (http://science.ncbo.noaa.gov/odst/), or printed maps. Additionally, use the bottom of the habitat requirements data sheet to record other factors you considered when identifying potential restoration sites (management, disease, current oyster density, or other factors).
2. Use the ODST to identify 2-4 potential restoration locations that meet the habitat requirements criteria for oysters throughout their life cycle. To do this your team will need to reference the following layers (at least):

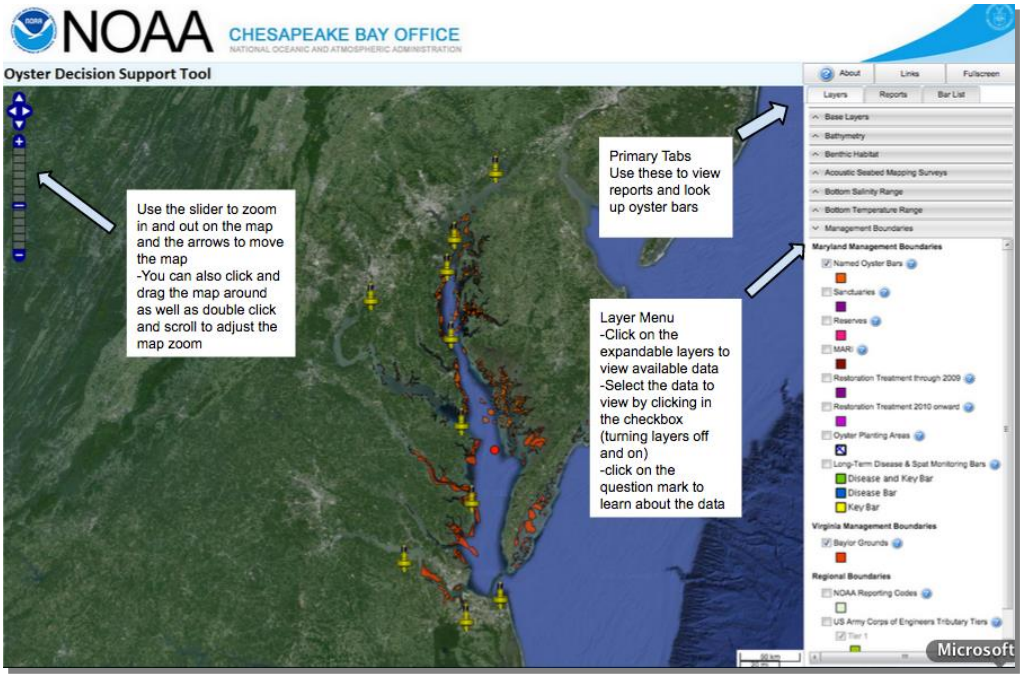
    a. Bathymetry (depth - generally <10meters and > 2m)
    b. Benthic Habitat (oysters prefer hard bottom - artificial reef, shell)

        NOTE: You can select to view only benthic habitats suitable for oysters by turning off some of the sub-layers.

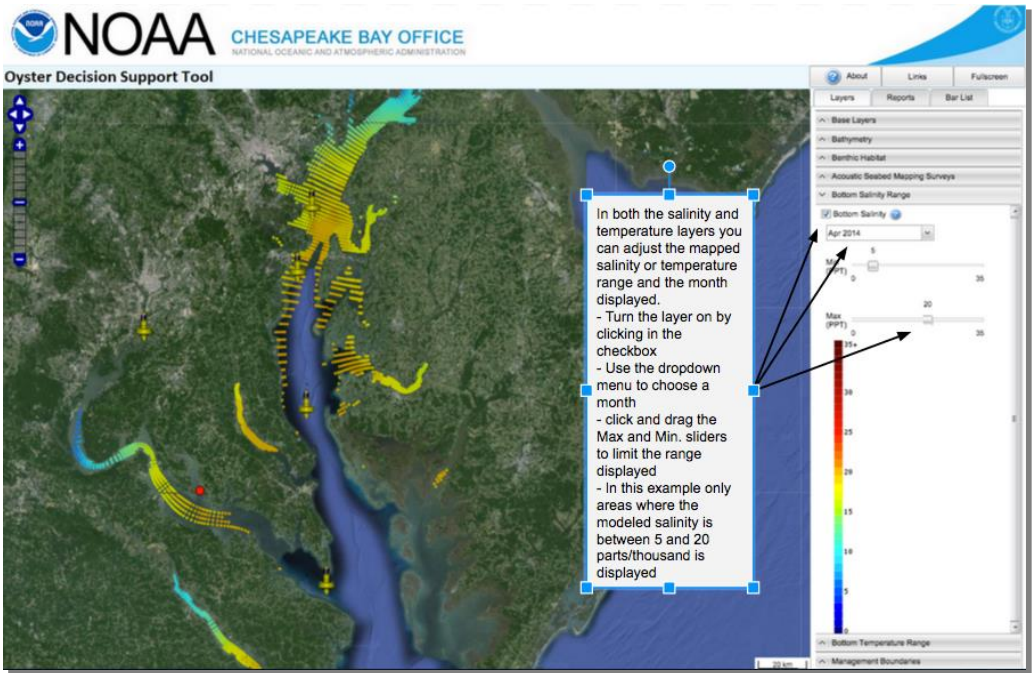
    c. Bottom Salinity and Temperature Range (students can set sliders in this layer to view salinity levels suitable for various oyster life stages)
    d. Management Boundaries - everything with the exception of sanctuaries is open to harvest
    e. Biological Data Maps - look for disease or areas where oysters are succeeding
    f. To evaluate Dissolved Oxygen in the targeted restoration areas, students will need to locate nearby monitoring stations or utilize other resources listed below:

        i. Real-time Data - Chesapeake Bay Interpretive Buoy System, http://buoybay.noaa.gov/locations
        ii. Real-time Data and long term monitoring data - Eyes on the Bay, http://mddnr.chesapeakebay.net/eyesonthebay/index.cfm
        iii. Modeled Data Chesapeake Bay Interpolator, http://archive.chesapeakebay.net/status/wquality/interpolator/do/gallery.htm
        iv. Sampling Data EcoCheck Chesapeake Bay Report Card, http://ian.umces.edu/ecocheck/report-cards/chesapeake-bay/2013/indicators/dissolved_oxygen/

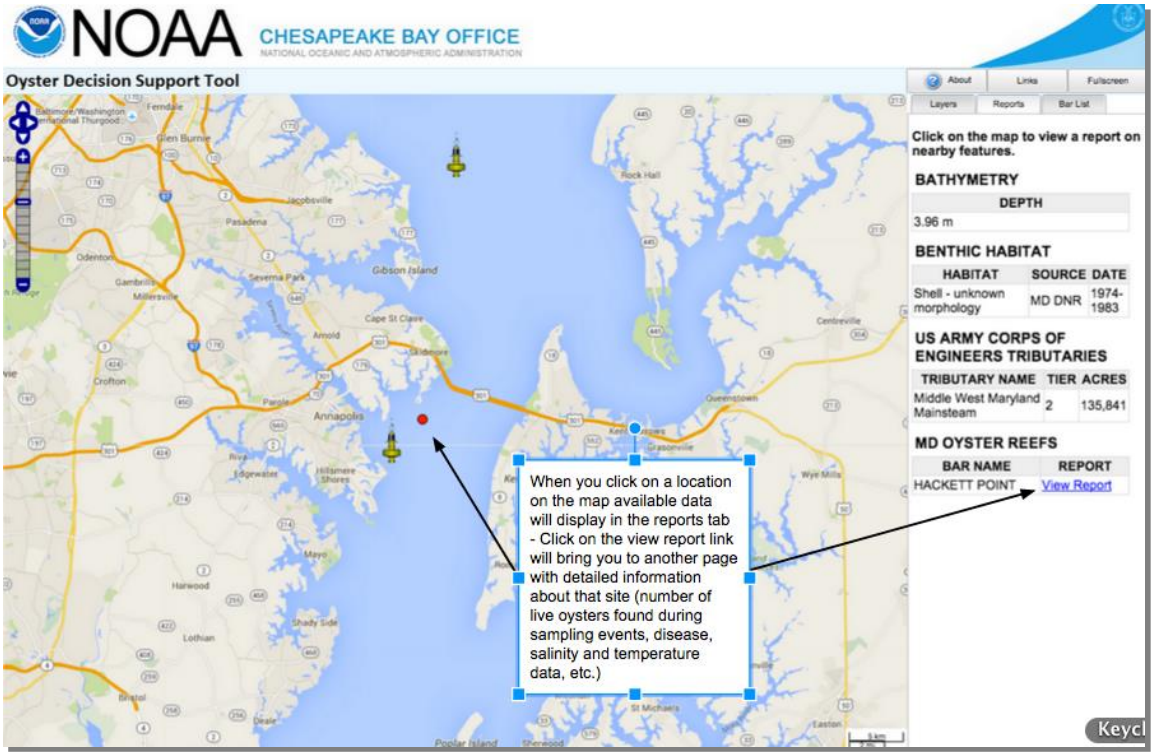
Basic ODST Layout:



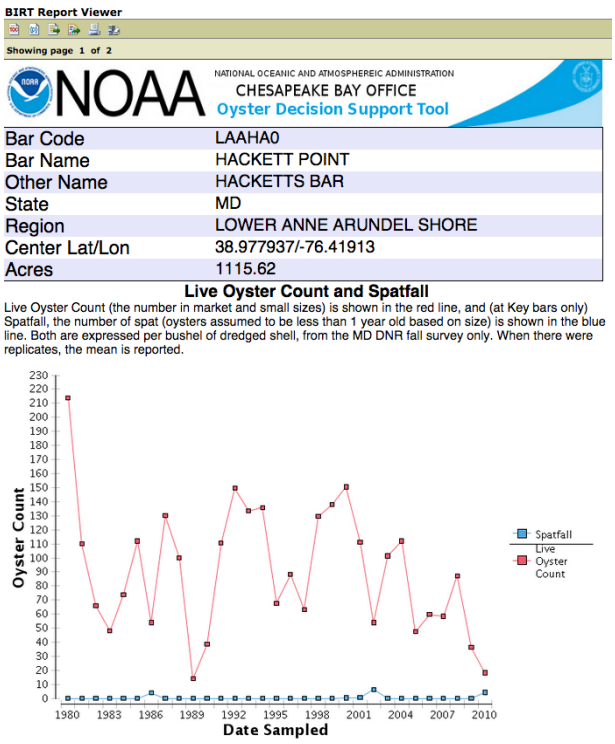
Using the Temperature and Salinity Layers:



Viewing Reports:



Sample Report from View Report Link:



ACTIVITY V: Communicating Your Proposed Oyster Sanctuary Management Plan

STUDENT PAGE

Choose one of the sites evaluated. Prepare a report for the Secretary of Natural Resources describing the selected restoration location and the reasoning for making this selection.

The report should include:

1. Location Information:
    a. Name of location (if already a named oyster bar, or made up based on site characteristics)
    b. Tributary or section of the Bay in which site is located
2. Factors considered
    a. Habitat Requirements
    b. Management
    c. Watershed Health
    d. Economic Considerations
3. Discussion of why location was chosen above other candidate locations
4. Discussion of positive and negative aspects of chosen location
5. References

EXTENSION: Evaluating an Oyster Sanctuary Plan for Harris Creek

STUDENT PAGE

1. Read the transcript for the public hearing on oyster restoration in Harris Creek.

   NOTE: The names of individuals and/or organizations and agencies are highlighted in yellow.

2. Discuss perspectives on restoration and oyster sanctuaries.
   1. Watermen/Boat Captains
   2. Non-Profit Organizations
   3. Scientists
   4. Resource managers
   5. Private citizens

3. Identify the "Stakeholder, Beliefs, and Values" in the transcripts (or a portion of transcripts). Use the Players, Beliefs and Values Chart from Module 1, APPENDIX C to analyze this transcript and record the variety of perspectives presented.