Module 3

Grade Level: High School

Teaching Time: 3 Class periods with some homework

Materials:

- Computers with internet access
- Student Pages
- Student Data Sheets
- Student Maps and articles

Teacher Note (optional):

- This activity works best if students have internet access. However, if internet access is not available students can use printed copies of maps, articles and other resources.
- There is a fair amount of group work in this module. Ideally, groups will be composed of 3-5 students.
- See **Resources** section for more detailed list of readings, web links, and other activity resources.

Oyster Restoration — Evaluating Habitat Requirements for the Eastern Oyster

In 2014, a new Chesapeake Bay Watershed Agreement, http://www.chesapeakebay.net/documents/ChesapeakeBayWatershedAgreemenetFINAL.pdf, was signed by New York, Pennsylvania, Maryland, Delaware, Virginia, West Virginia and the District of Columbia. The Agreement has at its heart a road map for protecting and restoring the Chesapeake Bay. Restoring oysters in the Chesapeake Bay for water quality, habitat, fisheries, and other ecosystem benefits is one of the goals of the new Agreement.

For specific information related to oysters, see page 4 of the Agreement, or view the Chesapeake Bay Program Restoring Oyster Reefs web pages at, http://www.chesapeakebay.net/indicators/indicator/restoring_oyster_reefs.

State governments, the federal government, universities, non-profits, citizens, and students have assisted with oyster restoration throughout the years by participating in programs like the Maryland Department of Natural Resources' *Marylanders Grow Oysters*, http://oysters.maryland.gov/, or the Chesapeake Bay Foundation's *Oyster Gardeners Program*,

http://www.cbf.org/how-we-save-the-bay/programs-initiatives/maryland/oyster-restoration/oyster-gardening-program.

Module 3 builds on the history of citizen and student involvement in oyster restoration efforts and asks students to think critically about where to place oysters after they have been raised by students, concerned citizens, or oyster restoration partners throughout the watershed.

If your school is close to a tributary of the Chesapeake Bay where there is a Chesapeake Bay Foundation or Marylanders Grow Oysters Program, or you work with non-profit partners involved in oyster restoration, consider getting your students involved in a hands-on oyster restoration experience.

SUMMARY

After completing the first two modules in this High School Unit, *An Historical Perspective of Oyster Related Environmental Issues,* and *Investigating Sustainable Resources Management Using the Fish Banks Simulation,* students have now learned a great deal about the value of oysters from both an historical perspective, and from that of the current men and women who harvest the resource, and those tasked with managing the resource. Ecological principles, technology, economics, policy, and culture all impact the oyster population. Students have read stories, news articles, journal articles, and other resources, which have emphasized how society influences natural resources, and how these resources are valued by people in the region. Students have also simulated a hypothetical fishing scenario where they made decisions and developed strategies for harvesting a sustainable resource, while maintaining their own quality of life in the *Fish Banks Simulation*.

In this module, students will focus on the habitat requirements of oysters, including what they need for both survival, and reproduction in Chesapeake Bay. The activities in this lesson focus on the biological and physical parameters necessary for oysters to live and thrive in the Bay ecosystem. Additionally, this module will help students understand how humans can have both positive and negative impacts on native oyster populations.

LEARNING OBJECTIVES

- Students will be able to describe the connections between biotic and abiotic conditions in Chesapeake Bay.
- Students will be able to apply data, evidence, and knowledge of biotic and abiotic conditions throughout the oysters' life cycle to make decisions about oyster restoration in the Chesapeake Bay.
- Students will be able to apply GIS data to support decision making.

GUIDING QUESTIONS

- What biotic and abiotic factors should be considered when restoring oysters and maintaining oyster survival throughout its various life stages?
- What natural resource management policies/factors should be considered when making decisions about oyster restoration?

BACKGROUND

Restoration of the Eastern oyster is an important component in the Chesapeake Bay Restoration effort. Based on information from the time of John Smith, we know oysters were plentiful throughout the Bay and a very important part of the ecosystem. This is why restoring oysters is an essential strategy in the Chesapeake Bay Agreement.

The Chesapeake Bay Agreement is the roadmap for improving environmental conditions in the Bay, and doing what we can to ensure the Bay looks and functions more like it did during John Smith's time. The first Chesapeake Bay Agreement was signed in 1983, and it recognized that scientific research addressing historical declines in the living resources of the Chesapeake Bay, such as oysters, required a cooperative approach to "fully address the extent, complexity, and sources of pollutants entering the Bay." The Environmental Protection Agency (EPA), the State of Maryland, the Commonwealths of Pennsylvania and Virginia, and the District of Columbia were the key players in the original Agreement. Their goal was to implement and coordinate management plans that would improve and protect the water quality and living resources of the Chesapeake Bay.

Since then, the Chesapeake Bay Agreement, http:/www.chesapeakebay.net/about/how/history, has been revised to address changing needs and issues. In 2014, a new Chesapeake Bay Watershed Agreement was signed by watershed states with new goals and strategies for protecting and restoring the Chesapeake Bay. This new plan for collaboration across the Bay's political boundaries establishes a vision for the restoration of the Bay, its tributaries and the lands that surround them. In addition to the original member states of Maryland, Virginia, and Pennsylvania, now Delaware, New York, and West Virginia are essential partners in this cooperative program.

Oysters are a ***keystone species*** in the Chesapeake, and because their population has declined significantly (as you have learned about in Modules 1 and 2, strategies to restore oysters are an important goal of the Chesapeake Bay Agreement.
http://education.nationalgeographic.com/education/encyclopedia/keystone-species/?ar_a=1
The *Oyster Outcomes,* listed under the Sustainable Fisheries Priority Goal, include:

1) Continually increase finfish and shellfish habitat and water quality benefits from restored oyster populations.

2) Restore native oyster habitat and populations to **TEN** tributaries by **2025** and ensure their protection.

During this activity, students will explore the environmental factors, stakeholder perspectives, and management strategies that are considered when making decisions about oyster restoration.

Click on http://www.chesapeakebay.net/fieldguide/critter/eastern_oyster to learn more about oysters, and on http://www.chesapeakebay.net/indicators/indicator/restoring_oyster_reefs to learn about oyster restoration.

Key Words

Abiotic – a nonliving (physical or chemical) component of the environment.

Algae – small, usually microscopic free-floating plants; the primary producers of food and oxygen in the Bay.

Bathymetry – pertaining to the depth and relief of water basins.

Benthic – bottom dwelling; defining a habitat or organism found on the sea bottom; of or pertaining to the bottom of a water body.

Benthos – organisms that live on or in the bottom of a body of water (e.g., ocean, river, stream, etc.)

Biotic – pertaining to the living components of their environment.

Dissolved Oxygen – the amount of oxygen dissolved present in the water, expressed in mg/L, or the number of milligrams of oxygen dissolved in a liter of water.

Ecology – the study of interrelationships between living things and their environment.

Gametogenesis – the process leading to the production of gametes; the development and maturation of reproductive cells through meiosis.

Habitat – the natural home or environment in which a plant, animal, or other organism lives, feeds, and/or breeds.

Keystone Species – a species whose survival affects the organisms in an ecosystem; a species that exerts a major influence on the composition and dynamics of the community in which it lives. If it were removed from the ecosystem, the ecosystem would change drastically.

Larva – the tiny, newly hatched, immature form of any animal when more or less of a metamorphosis takes place, before the assumption of the mature shape.

pH – a measure of the hydrogen ion (H^+) concentration of a solution. It is used to determine the acidity or alkalinity of a substance.

Parameter – a variable whose measure is indicative of a quantity or function that cannot itself be precisely determined by direct methods (e.g., water quality parameters, such as dissolved oxygen or turbidity indicate the "health" of a body of water).

Plankton – small free-floating plants, animals, and bacteria, with limited to no swimming ability.

Salinity – a measure of the salt concentration of the water. It is usually expressed in parts per thousand (ppt), or the number of grams of dissolved salts present in 1,000 grams of water.

Spat – juvenile oysters that have just attached to a hard surface.

Spawn – to release eggs and/or sperm into the water.

Turbidity – the clarity of the water; a measure of the amount of sunlight that can penetrate through the water.

VOCABULARY SOURCES:

Biology Online, http://www.biology-online.org/dictionary/Dissolved_oxygen

Chesapeake Bay Program – Bay Glossary, http://www.chesapeakebay.net/glossary

NOAA National Environmental Satellite, Data, and Information Service, https://www.ncdc.noaa.gov/paleo/ctl/glossary.html#j

NOAA Fisheries Glossary, https://www.st.nmfs.noaa.gov/st4/documents/FishGlossary.pdf

PROCEDURE

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

ENGAGEMENT

Students will describe the connections between biotic and abiotic conditions in Chesapeake Bay, and the effects of these factors on the Eastern oyster.

1. As a class, have a discussion about what animals in the Chesapeake Bay need to survive, and list these items on the board. They should consider biological, chemical, and physical parameters as they brainstorm. What are these parameters? Does each parameter have an optimum *range* (e.g., 0-32 ppt salinity) in which animals or plants can survive?

2. Divide the class into small groups of approximately 3-5 students each.

    a. During this section explain to the students that they are outlining the oyster's habitat requirements. The following links may be used to find basic information about oysters:

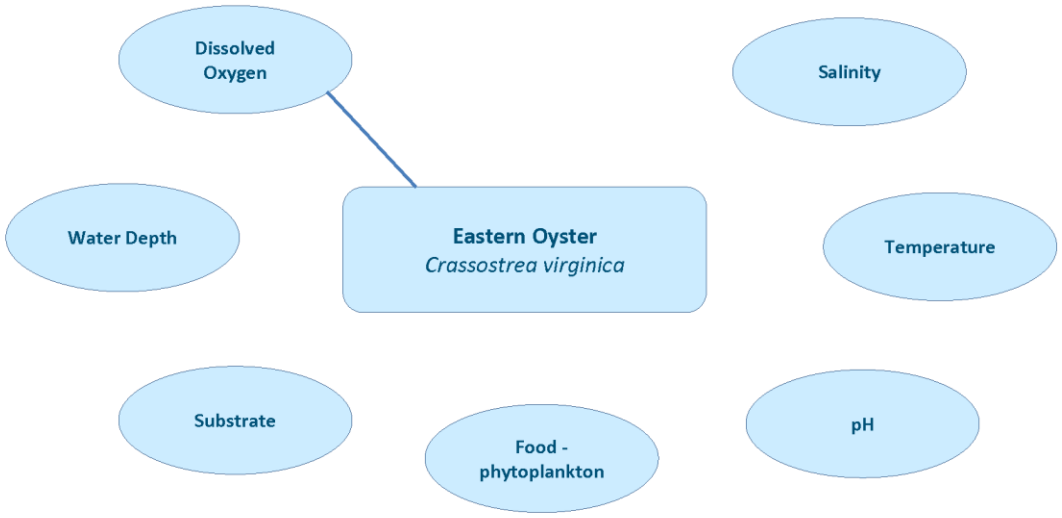
        Chesapeake Field Guide **– Chesapeake Bay Program**
        http://www.chesapeakebay.net/fieldguide/critter/eastern_oyster

***Oysters in the Environment*– Maryland Sea Grant**
http://ww2.mdsg.umd.edu/interactive_lessons/oysters/oysback.htm

Provide sufficient time for students to investigate these and other oyster-related resources.

b. Using the *Oyster Habitat Requirements Concept Map* template in APPENDIX B: Student Pages, instruct your students to create a concept map illustrating the biotic and abiotic criteria required for oyster survival based on class discussion and the information they gleaned from the sources above.

Oyster Habitat Requirement Concept Map



c. Ask the students to be as specific as possible (i.e., what kind of food do oysters need? Are water quality conditions supportive of the oysters' needs?)

d. Interactions between Earth's systems (hydrosphere, atmosphere, biosphere, etc.) can also be integrated here. Examples include:

   i. How does precipitation affect salinity, water clarity, etc., and how could these changes influence other water quality parameters? See the following resources for more background information:

   Monitoring Estuarine Water Quality at the NOAA Ocean Service below:
   http://oceanservice.noaa.gov/education/yos/lesson/Grades%205-8/water_quality_teacher_guide.pdf

National Estuarine Research Reserve System, *Estuary Education: Chemistry in an Estuary*, pp. 2-5
https://coast.noaa.gov/data/estuaries/pdf/chemistry-in-an-estuary-teacher-guide.pdf

Chesapeake Bay Program

- Sediment, http://www.chesapeakebay.net/videos/clip/bay_101_sediment
- Dissolved Oxygen, http://www.chesapeakebay.net/videos/clip/dissolved_oxygen
- Water Clarity, http://www.chesapeakebay.net/videos/clip/bay_101_water_clarity
- Oysters, http://www.chesapeakebay.net/videos/clip/bay_101_oysters

ii. How would a change in these habitat conditions affect oysters?

iii. How does land use influence Earth systems that, in turn, could affect oyster populations?

4. Now, have a discussion about current Chesapeake Bay water quality to guide student thinking about whether current conditions support oyster survival. A good source of information for current Bay conditions includes the Chesapeake Bay Interpretive Buoy System (CBIBS) at http://buoybay.noaa.gov and Eyes on the Bay at http://eyesonthebay.dnr.maryland.gov/eyesonthebay/. Search for other online water quality sources of data. Additional sites are provided in *the References and Resources* section for this Module. Local watershed groups in your region may also collect data that are useful (e.g., Midshore Riverkeepers Conservancy, http://www.midshoreriverkeeper.org/rivers/maps/). Also see the Chesapeake Bay Operational Forecast System, https://tidesandcurrents.noaa.gov/ofs/cbofs/cbofs.html.

   Are water quality conditions at a particular site supportive of oyster growth and/or reproduction based on what students have learned thus far?

5. Discuss how the oysters' habitat requirements may change throughout its life cycle. When determining where to permanently place oysters for restoration, it is important to consider these changes. (The oyster life cycle will be addressed in the next activity).

ACTIVITY II: The Oyster Life Cycle

EXPLORATION

The habitat requirements for oysters change throughout their life cycle. Environmental factors trigger biological responses in the oyster, such as in reproduction.

Provide students with the *Oyster Life Cycle* hand-out in APPENDIX B: Student Pages, or use the following links if computers and Internet access are available:

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

NOAA Chesapeake Bay Office
http://chesapeakebay.noaa.gov/fish-facts/oysters
(Have the students view the life history and habitat sections).

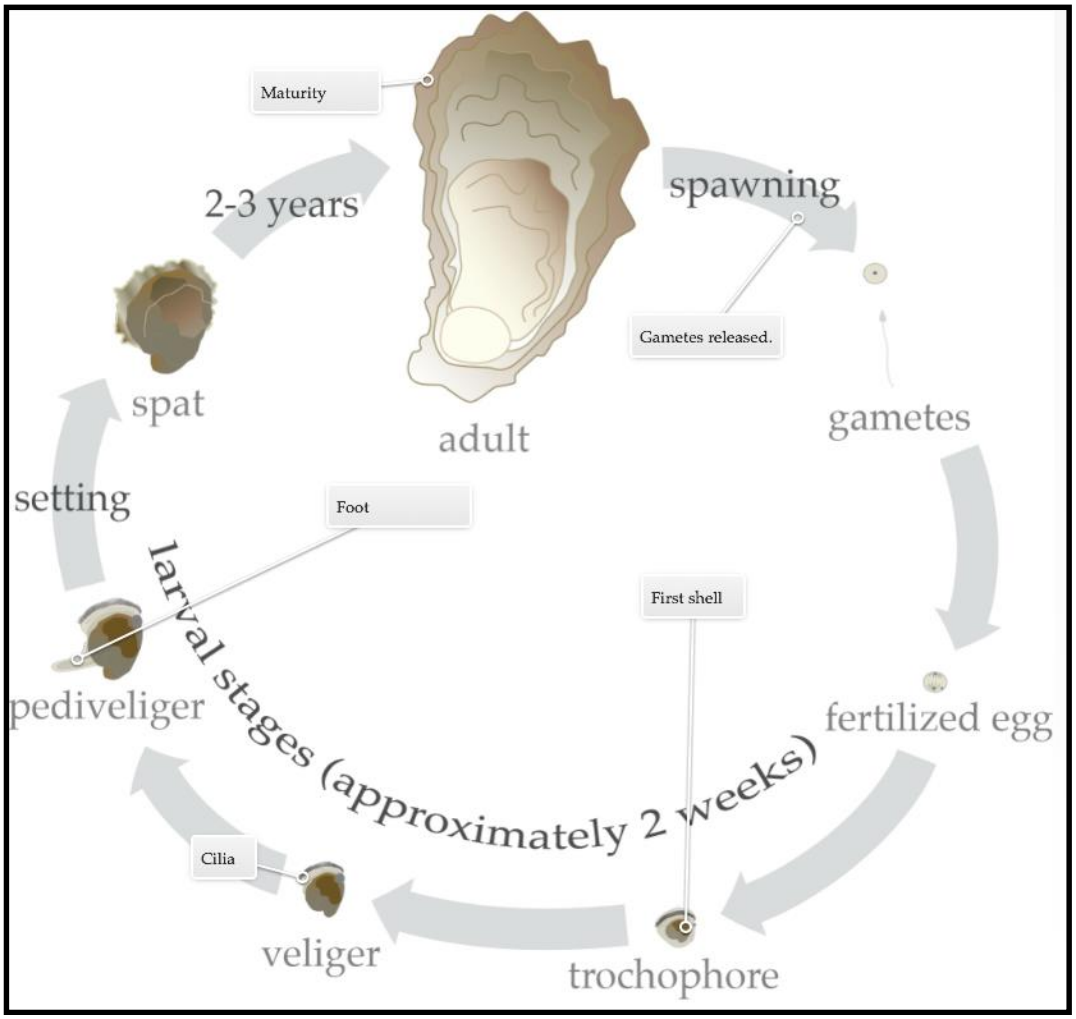
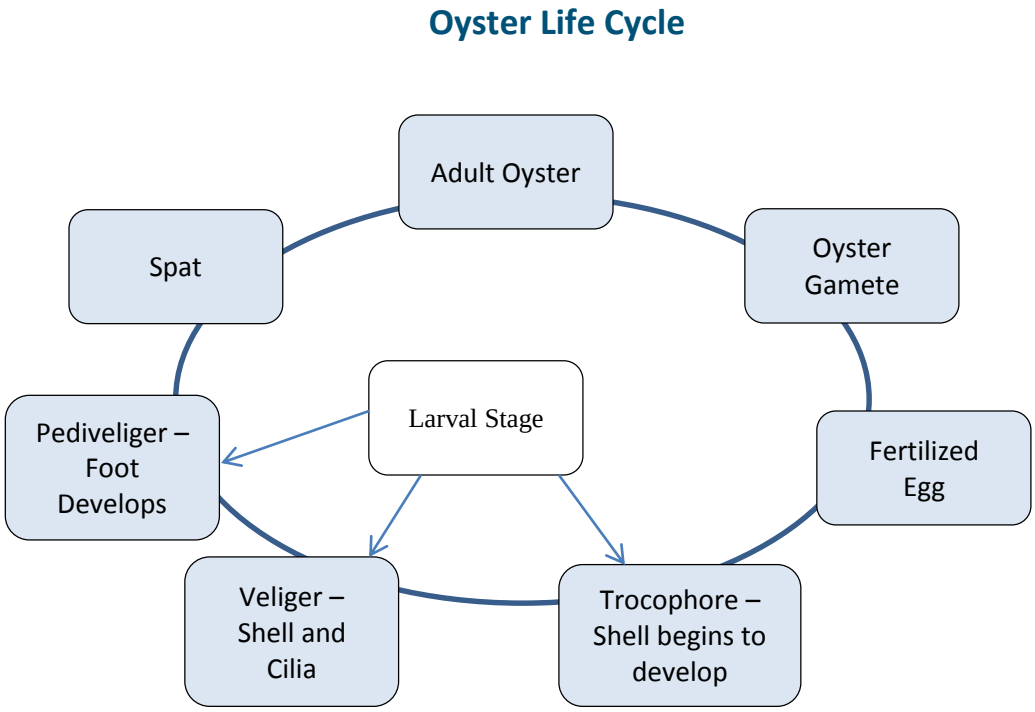


Diagram of Oyster Life Cycle
http://www.chesapeakedata.com/wp/
Used with permission from the *Chesapeake Bay Ecosystem Atlas;*
Chesapeake Environmental Communications 2015

In small groups, have students use the *Oyster Life Cycle* template in APPENDIX B: Student Pages and compare to the *Oyster Habitat Requirements Concept Map* that they worked on in ACTIVITY I to illustrate how habitat requirements may change depending on the life stage of the oyster. This concept map will be used again to illustrate additional interactions between oysters, and other environmental and human factors.

Below is a completed version of the Oyster Life Cycle template for students.



ACTIVITY III: Oyster Habitat Requirements Data Table

EXPLORATION/EXPLANATION

A great deal of scientific research has been done to better understand Chesapeake Bay oysters, and much is still going on today. Some of this research has looked at how water quality affects oyster survival and reproduction. In this section you will be using excerpts from *Habitat Requirements for Chesapeake Bay Living Resources*. (See APPENDIX C: Resources) This resource documents the water quality and other habitat requirements for numerous Bay species. We will be using this section on oysters to learn more about their specific needs throughout their many life stages.

1. Distribute the *Eastern Oyster* Chapter from *Habitat Requirements for Chesapeake Bay Living Resources* (Kennedy, 1991) in APPENDIX C: Resources.

TEACHER NOTE: Do not include the Tables at the end of the chapter when distributing to students. They will be completing a table as part of the Module activities. For your convenience, APPENDIX C provides the TABLE separate from the article.

Direct your students to read the *Introduction, Background,* and *Ecological Role* sections of the *Eastern Oyster* Chapter.

2. Divide your class into small groups of 3-5 students each. In each group, students should be assigned (or volunteer) to become "experts" on the following oyster habitat requirements.

    a. Water Temperature
    b. Salinity
    c. Dissolved Oxygen
    d. pH
    e. Structural Habitat (substrate and depth)

TEACHER NOTE: *If desired, two students could be assigned to the water temperature and salinity groups.*

Once assigned to, or having chosen, a section of the habitat requirements, students should read this section and use the information they find to fill out the *Oyster Habitat Requirements Data Table* in APPENDIX B: Student Pages. This chapter will provide an explanation of the various life stage conditions required.

A **completed** data table can be found in APPENDIX A: Teacher Pages. The table from the original article is in APPENDIX C: Resources.

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

ELABORATION

Students will apply data and evidence from secondary sources about biotic and abiotic conditions that oysters need to survive and reproduce in Chesapeake Bay. Applying new knowledge about the oyster life cycle and habitat conditions that support oyster survival through each life stage, they will form decisions regarding potential oyster restoration sites in the Chesapeake Bay.

1. Using the *Oyster Life Cycle Model* and the *Oyster Habitat Requirements Data Table*, students should modify and further develop their *Oyster Habitat Requirements Concept Map* from ACTIVITY I.

They should 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, drought, etc.).

2. Have students use the following resources and experiences as they develop their concept map.
   - Oyster Habitat Requirements Chapter; 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) https://drive.google.com/open?id=0B-1W5S46ODQNM2V3ZDQzWGQ5SkU
     - Maryland Department of Natural Resources, Annual Fall Survey Reports Provide Maryland Oyster Population Status Reports from 1996-2015 (as of April 2017) at http://dnr2.maryland.gov/fisheries/Pages/shellfish-monitoring/reports.aspx.

EVALUATION

Concept Map Discussion

When complete, students will share their concept maps with the class, and discuss and compare the unique components they included. Ask them how they could use this information to identify locations within the Chesapeake Bay that they would target for oyster restoration.

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

ELABORATION

Students will apply their knowledge about the oyster life cycle, and habitat conditions that support oyster survival within each life stage to make decisions regarding potential oyster restoration sites in the Chesapeake Bay.

In this activity students will use what they have learned about the oyster's habitat requirements, and other important factors that influence their population to identify a specific location for targeted oyster restoration. During this activity they will use the **NOAA Oyster Decision Support Tool (ODST)** to analyze available data, and identify potential restoration locations, http://science.ncbo.noaa.gov/odst/. GIS data will help support decision making using the ODST.

TEACHER NOTE: If there are problems with the ODST site, use the websites listed under Water Quality in the References section to help you find data. Please, contact us if you have any issues.

About the Oyster Decision Support Tool

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 method to access information on oysters, oyster habitat, and oyster restoration projects in Chesapeake Bay. Data for the ODST came from state and federal agencies working in the Chesapeake, scientists, academic institutions, and nonprofit organizations. 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

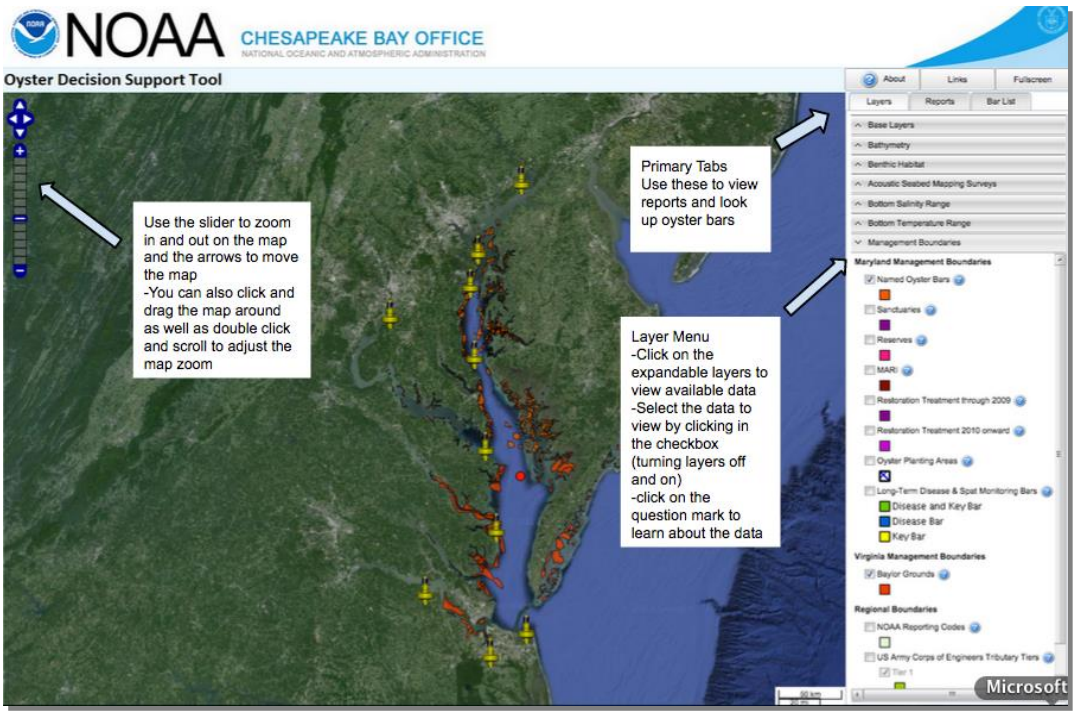
TEACHER NOTE*: The ODST may have a bit of a hiccup in the system in that, on some computers when you first view the mapping tool, all you see is some orange shapes illustrating the named oyster bars in the Maryland portion of the Chesapeake Bay. To get the rest of the map to show up, click on the Base Layers (on the right side of your map under the layers tab) and click on the different base layers until the one you want renders on your screen.*

Using the Oyster Decision Support Tool

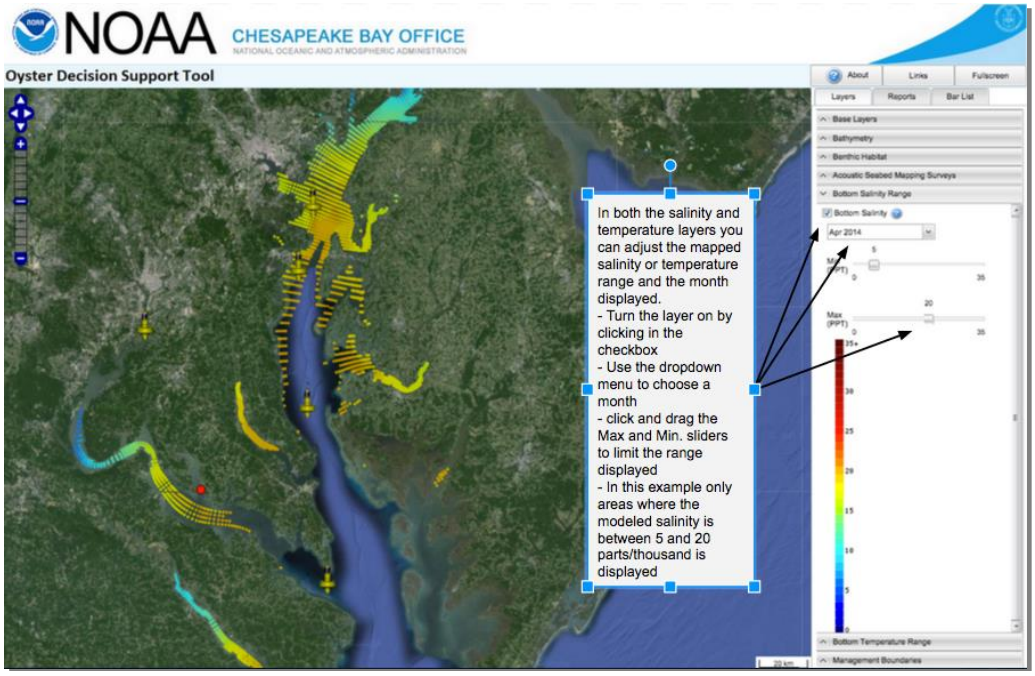
Like Google Earth, FieldScope and other GIS/Map resources, the ODST is a collection of data that you can visualize and ask questions about. Here are some tips for using the tool:

- Users have the ability to turn on and off many data layers. 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.

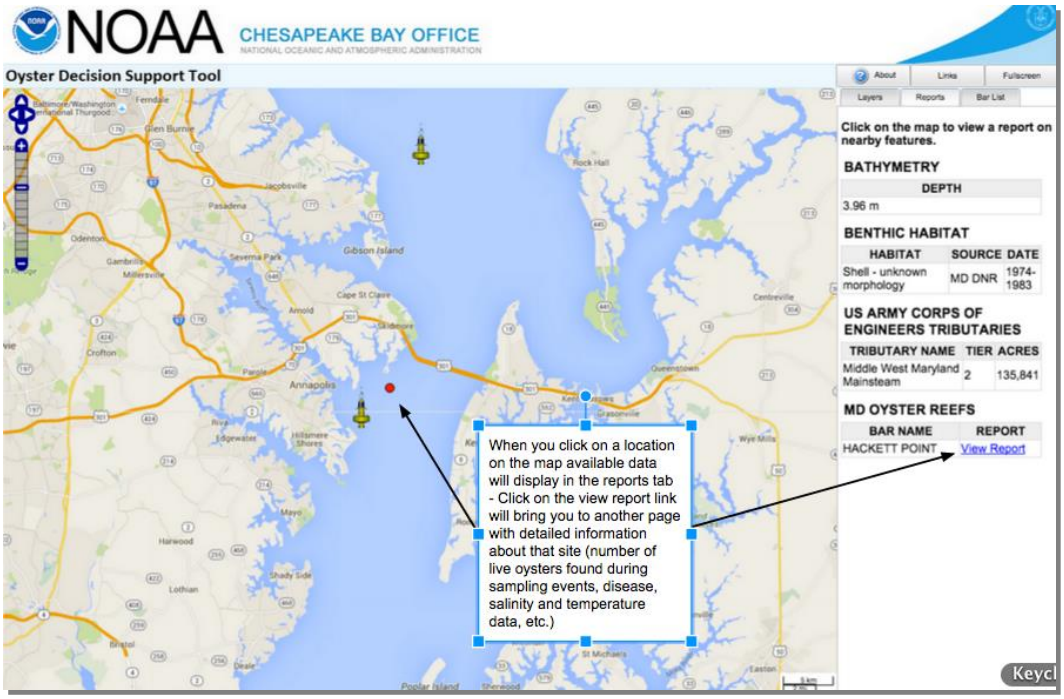
Basic ODST Layout:



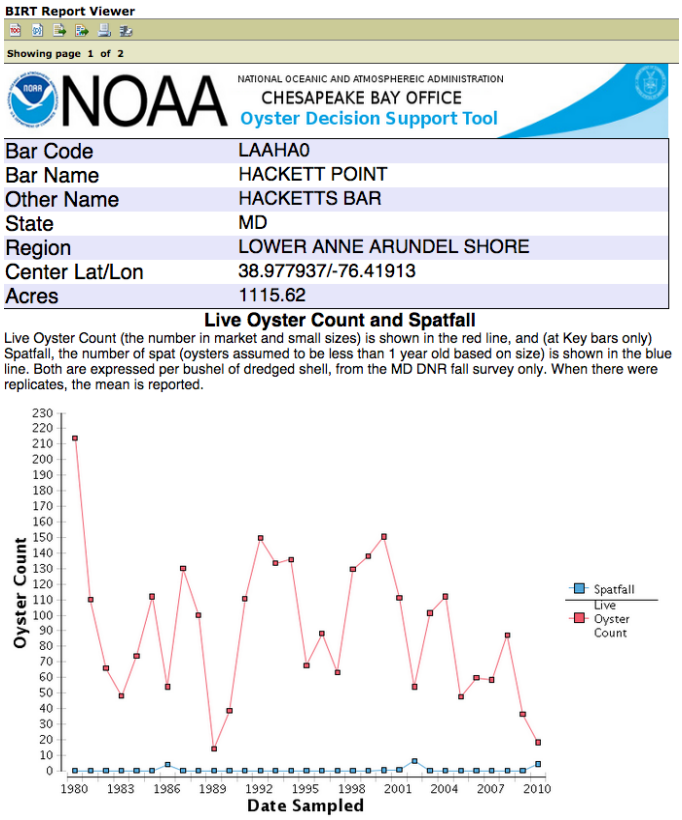
Using the Temperature and Salinity Layers:



Viewing Reports:



Sample Report from View Report Link:


BIRT Report Viewer

Showing page 1 of 2

NOAA NATIONAL OCEANIC AND ATMOSPHEREIC ADMINISTRATION
CHESAPEAKE BAY OFFICE
Oyster Decision Support Tool

Bar Code	LAAHA0
Bar Name	HACKETT POINT
Other Name	HACKETTS BAR
State	MD
Region	LOWER ANNE ARUNDEL SHORE
Center Lat/Lon	38.977937/-76.41913
Acres	1115.62

Live Oyster Count and Spatfall

Live Oyster Count (the number in market and small sizes) is shown in the red line, and (at Key bars only) Spatfall, the number of spat (oysters assumed to be less than 1 year old based on size) is shown in the blue line. Both are expressed per bushel of dredged shell, from the MD DNR fall survey only. When there were replicates, the mean is reported.

TEACHER NOTE: See copies of the maps above in a larger format in APPENDIX C: Resources. Oyster restoration examples from both Maryland and Virginia using oyster data and maps are available here.

Oyster Decision Support Tool Procedure

1. Divide class into small groups of approximately 3-5 students each. Explain that they will be taking on the role of an oyster management team charged with identifying a site for oyster restoration activities. This can be done throughout the Chesapeake or narrowed down to a local tributary. Students will reference their oyster concept map and habitat requirements data table to evaluate potential restoration locations using the Oyster Decision Support Tool, or printed maps. (See Maryland and Virginia maps in APPENDIX C: Resources. Additional links to maps and data can be found in the *References and Resources* section of this Module).

2. Additionally, students can use the bottom of the habitat requirements data sheet to record other factors they considered when identifying potential restoration sites (management, disease, current oyster density, etc.).

3. Instruct students to use the ODST to identify 2-4 potential restoration locations that meet the habitat requirements criteria for the entire oyster life cycle. To do this they will need to reference the following layers (at least):

    a. Bathymetry (depth - generally <10m and > 2m)

    b. Benthic Habitat (oysters prefer hard bottom - artificial reef, shell)

    TEACHER NOTE*:* Students can make a selection 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 or other water quality parameters 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

        iii. Real-time and Long Term Monitoring Data – *Maryland Eyes on the Bay*, http://mddnr.chesapeakebay.net/eyesonthebay/index.cfm

        iv. Modeled Data - *Chesapeake Bay Interpolator*, http://archive.chesapeakebay.net/status/wquality/interpolator/do/gallery.htm

        v. Sampling Data - *EcoCheck Chesapeake Bay Report Card*, http://ian.umces.edu/ecocheck/report-cards/chesapeake-bay/2013/indicators/dissolved_oxygen/

        vi. Continuous, Real-Time and Long-Term Data, Virginia Estuarine and Coastal Observing System, http://web2.vims.edu/vecos/

4. Students should choose one of the sites they evaluated and be prepared, through reports or presentations, to explain why the site was chosen for oyster restoration.

ACTIVITY VI: Communicating Your Proposed Oyster Sanctuary Management Plan

EVALUATION

Have each group of students prepare a report for the Secretary of Natural Resources describing the selected restoration location and the reasoning that supports their 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. A discussion of why the location was chosen above other candidate locations.
4. A discussion of both positive and negative possibilities of the chosen location.

EXTENSION

1. Consider raising oysters, monitoring growth and habitat function (critters attached to oysters over time).

    Marylanders Grow Oysters, http://oysters.maryland.gov/, and the Chesapeake Bay Foundation, http://www.cbf.org/how-we-save-the-bay/programs-initiatives/maryland/oyster-restoration/oyster-gardening-program, are both potential partners working on oyster restoration. If possible, plan a field experience to selected restoration sites.

2. Read the transcripts from the public hearing on oyster restoration (2005) in Harris Creek in APPENDIX C: Resources. Divide students into smaller groups, and assign each group pages to analyze for *Environmental Issues.*

    Have students identify the *Stakeholders, Beliefs, and Values* in the transcripts. Where do the stakeholders stand on the issue? Use the Players, Beliefs, and Values Chart from **Module 1** APPENDIX C: IEEIA Resources to analyze the sanctuary issue, and record the perspectives presented.

The issue they are analyzing in this exercise is as follows:
Should oyster sanctuaries be placed in Harris Creek, Talbot County, Maryland?

TEACHER NOTE: Have students identify and highlight the stakeholders' name, organization, or occupation, if known, as they read through the assigned pages. It will make it easier for them to go back and record the information they need for the analysis.

After student groups have completed this exercise, discuss as a class the perspectives of the stakeholders on restoration and oyster sanctuaries, including, but not limited to:

a. Watermen/Boat Captains
b. Non-Profit Organizations
c. Scientists
d. Resource managers
e. Private citizens
f. Other

3. Set up a mock town hall meeting in which students represent the variety of perspectives represented in the transcript and discuss the merits of a sanctuary based oyster restoration strategy. http://www.readwritethink.org/resources/resource-print.html?id=31105

EDUCATION STANDARDS

Standard Category	*Standards*	*How Standard is Addressed*
NGSS – Disciplinary Core Idea(s)	**HS-LS2.A - Interdependent Relationships in Ecosystems** Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors and the availability of living and non-living resources and from such challenges as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance of species in any given ecosystem. **LS2.C - Ecosystem Dynamics, Functioning, and Resilience** A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystem in terms of resources and habitat availability.	**LS2.A - Interdependent Relationships in Ecosystems** Throughout this activity students will learn about the habitat requirements for oysters such as water quality conditions, bottom type etc. and that not all locations in the Chesapeake can support a sustainable oyster population. Oyster disease is also touched on briefly (which has implications related to non-native species). **LS2.C - Ecosystem Dynamics, Functioning, and Resilience** In Modules 1 and 2 of this Unit, students learned about large scale disturbances to oyster populations. In this activity students focus on oyster restoration as a way to restore ecosystem functions. This aspect could be further developed by adding complexity to the concept model activities.

NGSS – Disciplinary Core Idea(s)	**LS4.D Biodiversity and Humans** Biodiversity is increased by the formation of new species and decreased by the loss of species. Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through over-population, over exploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus, sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes or recreational or inspirational value.	**LS4.D Biodiversity and Humans** In this activity students will consider how human activity can address problems created by disease and over exploitation in the past to restore ecosystem function and prop up populations for ecological, as well as economic, recreational, and other reasons.
NGSS - Science and Engineering Practices	**Developing and Using Models** Develop a model based on evidence to illustrate the relationships between systems or components of a system **Analyzing and Interpreting Data** Analyze data using tools, technologies, and/or models in order to make valid and reliable scientific claims or determine optimal design solution Analyze data to identify design features or characteristics of the components of a system to optimize it relative to criteria for success **Using Mathematics and Computational Thinking** Use mathematical, computational, and/or algorithmic representations of	**Developing and Using Models:** Using readings and developing conceptual models, students illustrate relationships within an ecosystem. **Analyzing and Interpreting Data** When utilizing the Oyster Decision Support Tool, students analyze geographic, sampled, and modeled data to inform the siting of oyster restoration efforts most likely to result in the desired outcomes (e.g., increased oyster populations or oysters of market size). **Using Mathematics and Computational Thinking** Students use representations of modeled data to look at water

NGSS – Science and Engineering Practices	phenomena to describe and/or support claims and/or explanations. **Constructing Explanations and Designing Solutions** Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. **Engaging in Argument From Evidence** Evaluate claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence, challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining additional information required to resolve contradictions. Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence. Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence. Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empir-ical evidence, and/or logical arguments regarding relevant factors	quality parameters related to oyster productivity. **Constructing Explanations and Designing Solutions** Students use available data and resources to identify appropriate restoration sites. **Engaging in Argument From Evidence** Using scientific data and the Oyster Decision Support Tool, students make decisions about siting oyster restoration efforts, and evaluate restoration siting plans of their peers. Students evaluate the economic, ecological, and societal arguments for oyster restoration using the transcripts from a Public Hearing on the creation of oyster sanctuaries in a specific Chesapeake Bay tributary.

NGSS - Crosscutting Concepts	(e.g. economic, societal, ecological, environmental, ethical considerations). **Cause and Effect:** In grades 9-12, students understand that empirical evidence is required to differentiate between cause and correlation and to make claims about specific causes and effects. They suggest cause and effect relationships to explain and predict behaviors in complex natural and designed systems. They also propose causal relationships by examining what is known about smaller scale mechanisms within the system. They recognize changes in systems may have various causes that may not have equal effects. **Systems and System Models** In grades 9-12, students can investigate or analyze a system by defining its boundaries and initial conditions, as well as its inputs and outputs. They can use models (e.g., physical, mathematical, computer models) to simulate the flow of energy, matter, and interactions within and between systems at different scales. They can also use models and simulations to predict the behavior of a system, and recognize that these predictions have limited precision and reliability due to the assumptions and approximations inherent in the models. They can also design systems to do specific tasks. **Stability and Change:**	**Cause and Effect:** Students work with the existing research on oysters and their life cycles to identify the effect of changes in water chemistry on the oysters and their habitat. **System and System Models** Students look at oyster habitat to determine inputs and outputs that impact the oyster reef. Students may also use model data on salinity and temperature to determine sites for restoring oysters. **Stability and Change:** Students consider the “permanent”

NGSS - Crosscutting Concepts	In grades 9-12, students understand much of science deals with constructing explanations of how things change and how they remain stable. They quantify and model changes in systems over very short or very long periods of time. They see some changes are irreversible, and negative feedback can stabilize a system, while positive feedback can destabilize it. They recognize systems can be designed for greater or lesser stability.	placement of oysters. This will occur in the context of both changing environmental conditions (temperature, salinity, dissolved oxygen) and changing management approaches. The use of sanctuaries for oyster restoration is an example of how systems are designed to support stability.
Connections to Common Core	**Reading Standards for Literacy in Science and Technical Subjects** ***R1 CCR Anchor Standard*** Read closely to determine what the text says explicitly and to make logical inferences from it; cite specific textual evidence when writing or speaking to support conclusions drawn from the text. Cite strong and thorough textual evidence to support analysis of what the text says explicitly as well as inferences drawn from the text, including determining where the text leaves matters uncertain. • Demonstrate the behaviors of a strategic reader. • Evaluate available evidence for thoroughness, completeness, and relevance. • Participate actively and appropriately in discussions about informational text. • Interpret, explain, and apply appropriate academic and/or domain-specific vocabulary when responding and discussing informational text. (See CCSS L.11-12.4 & L.11-12.6)	**Reading Standards for Literacy in Science and Technical Subjects** ***R1 CCR Anchor Standard*** Students review scientific articles and research data to determine healthy oyster habitat for the entire life cycle of the Eastern oyster, including larval stages. Students read and analyze the transcripts of a public hearing about the creation and location of an oyster sanctuary in Chesapeake Bay to determine the stake-holders, beliefs, and values surrounding the issue. Students must consider the societal, as well as ecological considerations when making a decision about oyster restoration sites.

Connections to Common Core	• Use knowledge of language and its conventions when speaking and writing. **RI7 CCR Anchor Standard** Integrate and evaluate content presented in diverse formats and media, including visually and quantitatively, as well as in words. Integrate and evaluate multiple sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a question or solve a problem. **Writing Standards** **CCR Anchor Standard #2** Write informative/explanatory texts to examine and convey complex ideas and information clearly and accurately through the effective selection, organization, and analysis of content. - WHST.11-12.2 Write informative/ explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes. **Mathematics** **MP.2:** Reason abstractly and quantitatively.	**RI7 CCR Anchor Standard:** Students develop and write an oyster sanctuary plan to the Secretary of Natural Resources using evidence from a report that uses scientific data to support the reason for the oyster restoration location that they chose. They also analyze the issue of creating sanctuaries, and how it affects stakeholders using the transcripts from a public hearing. **Writing Standards** **CCR Anchor Standard #2** Students develop, and write an oyster sanctuary plan to the Secretary of Natural Resources using evidence from a scientific text to support the reason for the oyster restoration location that they chose. In the EXTENSION section, they analyze the issue of creating sanctuaries, and how it affects stakeholders using the transcripts from a public hearing. **MP.2:** Students analyze data to make a claim supported by evidence.

MD Environmental Literacy Standards	**Standard 1.0: Environmental Issues** **Topic A: Environmental Issue Investigation** **Indicator 1:** Identify an environmental issue. • The student will recognize that real problems have more than one solution, and decisions to accept one solution over another are made on the basis of many issues. • The student will investigate a biological (or environmental) issue and be able to defend their position. **Indicator 3.** Given a specific issue, communicate the issue, the stakeholders involved, and the stakeholders' beliefs and values. **Standard 4: Populations, Communities and Ecosystems** The student will use physical, chemical, biological, and ecological concepts to analyze and explain the interdependence of humans and organisms in populations, communities, and ecosystems. **Standard 5: Humans and Natural Resources** The student will use concepts from chemistry, physics, biology, and ecology to analyze and interpret both positive and negative impacts of human activities on earth's natural systems and resources.	**Standard 1.0: Environmental Issues** **Topic A: Environmental Issue Investigation** Students are provided scientific data and human perspectives to make a decision about a locally relevant environmental issue. They must defend their position of where to target oyster restoration in written form. **Indicator 3.** In the EXTENSION, students are provided transcripts from a public hearing about the creation of an oyster sanctuary in Harris Creek, Talbot County Maryland. They analyze and evaluate the stakeholders, beliefs, and values involved with this specific issue. **Standard 4: Populations, Communities and Ecosystems** Students evaluate biotic and abiotic conditions of a healthy oyster population, and explain how abiotic factors influence one another, as well as the organisms in the ecosystem. Oysters provide food, habitat, and filter the water, and they also represent economic values in human communities. **Standard 5: Humans and Natural Resources** The actions that humans take on land can have negative and positive effects on the biotic and abiotic factors within that system (e.g., water quality and its effect on oysters)

Module References

Below is a list of web links from this module in the order they appear in the lessons. This list is intended to be used with printed copies of this resource.

Chesapeake Bay Watershed Agreement 2014
http://www.chesapeakebay.net/chesapeakebaywatershedagreement/page

Chesapeake Bay Program Restoring Oyster Reefs web pages
http://www.chesapeakebay.net/indicators/indicator/restoring_oyster_reefs

MD DNR Marylanders Grow Oysters - http://oysters.maryland.gov

Oysters in the Environment– Maryland Sea Grant
http://ww2.mdsg.umd.edu/interactive_lessons/oysters/oysback.htm

Oyster Gardeners Program
http://www.cbf.org/how-we-save-the-bay/programs-initiatives/maryland/oyster-restoration/oyster-gardening-program

Keystone Species - http://nationalgeographic.org/encyclopedia/keystone-species/

Eastern Oyster - http://www.chesapeakebay.net/fieldguide/critter/eastern_oyster

Oyster Restoration – Chesapeake Bay Program – Restoring Oyster Reefs
http://www.chesapeakebay.net/indicators/indicator/restoring_oyster_reefs

Chesapeake Environmental Communications 2015, *Diagram of Oyster Life Cycle,* in *Chesapeake Bay Ecosystem Atlas;* http://www.chesapeakedata.com/wp/

Other Resources

Maryland Sea Grant
http://www.mdsg.umd.edu/

Maryland Sea Grant Education Programs
http://www.mdsg.umd.edu/our-education-programs

Leffler, Merrill. (1999, July-August). *Oyster Sanctuaries: An Ecological Approach to Restoration*. Maryland Marine Notes. MD Sea Grant, Volume 17, Number 4. Retrieved from
http://www.mdsg.umd.edu/sites/default/files/files/MN17_4.PDF

Oysters in the Classroom
http://www.mdsg.umd.edu/topics/k-12-lesson-plans/oysters-classroom

NOAA Chesapeake Bay Office

Acoustic Seafloor Mapping (See Chesapeake Bay Mapping Projects)
https://chesapeakebay.noaa.gov/acoustic-seafloor-mapping/acoustic-seafloor-mapping

Chesapeake Bay Interpretive Buoy System
https://buoybay.noaa.gov/observations/

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

Oyster Facts
http://www.chesapeakebay.noaa.gov/fish-facts/oysters

Oyster Restoration (Maryland and Virginia Projects and Updates)
https://chesapeakebay.noaa.gov/oysters/oyster-restoration

Seabed Mapping Tool for Oyster Restoration
https://chesapeakebay.noaa.gov/oysters/oyster-restoration-mapping-support

Chesapeake Bay Program
http://www.chesapeakebay.net/

Chesapeake Bay Oyster Sanctuary Plan, 2004
http://www.chesapeakebay.net/content/publications/cbp_12889.pdf

Maryland Department of Natural Resources (DNR)

Maryland Eyes on the Bay
http://eyesonthebay.dnr.maryland.gov/ (Click on Current Conditions or Data tabs)

Data Types Overview
http://eyesonthebay.dnr.maryland.gov/eyesonthebay/DataTypes.cfm

Continuous Monitoring Data Charts
http://eyesonthebay.dnr.maryland.gov/contmon/ConMonDataCharts.cfm

Current Conditions
http://eyesonthebay.dnr.maryland.gov/eyesonthebay/currentconditions.cfm

Fixed Station Monthly Monitoring
http://eyesonthebay.dnr.maryland.gov/bay_cond/station_select.cfm

Maryland's Historic Oyster Bars
http://dnr2.maryland.gov/fisheries/Pages/oysters/bars.aspx

http://dnr2.maryland.gov/fisheries/Documents/HistoricOysterBarNamesappended.pdf

Oyster Advisory Commission
http://dnr2.maryland.gov/fisheries/Pages/mgmt-committees/oac-index.aspx

Maryland Sanctuaries
http://dnr2.maryland.gov/fisheries/Pages/oysters/sanctuaries.aspx
http://dnr2.maryland.gov/fisheries/Pages/mgmt-committees/oac-index.aspx

Maryland Shellfish Related Programs
http://dnr.maryland.gov/fisheries/Pages/oysters/index.aspx

Maryland Aquaculture Siting Tool (This tool is used for regulatory purposes and doesn't provide biological data).
http://gisapps.dnr.state.md.us/Aquaculture/

Oyster Recovery Partnership
http://oysterrecovery.org/

Oyster Restoration in Virginia

Chesapeake Bay Foundation, 2010
On the Brink: Chesapeake's Native Oysters
http://www.cbf.org/document.doc?id=523

Chesapeake Bay Foundation – Oyster Restoration in MD and VA
http://www.cbf.org/about-cbf/offices-operations/oyster-restoration-centers

Oyster Gardening
http://www.deq.virginia.gov/Programs/CoastalZoneManagement/CZMIssuesInitiatives/Oysters/Gardening.aspx

Virginia Coastal Zone Management Program Oyster Restoration Efforts
http://www.deq.virginia.gov/Programs/CoastalZoneManagement/CZMIssuesInitiatives/Oysters.aspx

Virginia Oyster Restoration Center (VAORC) and Oyster Farm
http://www.cbf.org/about-cbf/offices-operations/oyster-restoration-centers/virginia-oyster-restoration-center-and-farm

Water Quality Resources

Chesapeake Bay Interpretive Buoy System, https://buoybay.noaa.gov/

Chesapeake Bay Program Water Quality Database (1984-present)
http://www.chesapeakebay.net/data/downloads/cbp_water_quality_database_1984_present

Chesapeake Fieldscope http://chesapeake.fieldscope.org/v3

Salinity Data Map http://chesapeake.fieldscope.org/v3/maps/1380

Appalachian Laboratory http://alese.al.umces.edu/chesapeakeFieldscope.html

MD Eyes on the Bay – Links to other Bay internet resources
http://eyesonthebay.dnr.maryland.gov/eyesonthebay/links.cfm

Maryland Water Quality Monitoring Organizations
http://mde.maryland.gov/programs/water/TMDL/Integrated303dReports/Pages/wqlinks.aspx

National Estuarine Research Reserve System – Centralized Data Management System
http://cdmo.baruch.sc.edu/ and http://cdmo.baruch.sc.edu/get/landing.cfm

- Real Time Monitoring – *Choose Reserve* (Chesapeake Bay, MD or VA)
- Data Export System
  http://cdmo.baruch.sc.edu/get/export.cfm
  - *Choose Reserve* (Chesapeake Bay, MD or VA)
  - Choose a station within the Reserve – A table with various stations comes up; note the column Data Type

Virginia Department of Environmental Quality
http://deq.state.va.us/Programs/Water/WaterQualityInformationTMDLs/WaterQualityMonitoring.aspx

Virginia Estuarine and Coastal Observing System (VECOS), http://web2.vims.edu/vecos/

Waterkeepers Chesapeake (Look for Waterkeeper or Riverkeeper Organizations on a river near you). www.waterkeeperschesapeake.com/

Field Trip Suggestions

Visit **Bay Backpack** at http://baybackpack.com/field_studies/

Chesapeake Bay Foundation http://www.cbf.org

Horn Point Laboratory http://www.umces.edu/k-12

Midshore Riverkeepers http://www.midshoreriverkeeper.org/program-overview/education-outreach/

Curriculum References

Maryland Environmental Literacy Curricular Infusion by Grade-band
http://marylandpublicschools.org/programs/Pages/Environmental-Education/elci_gb.aspx

Maryland Environmental Literacy Standards
http://marylandpublicschools.org/programs/Documents/Environmental/MDEnvironmentalLitStandards.pdf

National Council for the Social Studies (NCSS), The College, Career, and Civic Life (C3) Framework for Social Studies State Standards: Guidance for Enhancing the Rigor of K-12 Civics, Economics, Geography, and History (Silver Spring, MD: NCSS, 2013).

Next Generation Science Standards: For States, By States
http://www.nextgenscience.org/

NGSS Lead States. 2013. *Next Generation Science Standards: For States, By States*. Washington, DC: The National Academies Press.
The College, Career, and Civic Life (C3) Framework for Social Studies State Standards, http://www.socialstudies.org/sites/default/files/c3/C3-Framework-for-Social-Studies.pdf