Module 2

Grade Level: High School

Teaching Time: 2-3 class periods with some homework

Materials:
   (1) Computer and (1) printer – **Fish Banks Game Kit***
OR
   (1) Computer per team – **MIT Fish Banks simulation***
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• Projector and screen
• Teacher pages (available through MIT Website or the Game Kit)
• Role Description for each student (available through MIT Website or the Game Kit)
• Student pages
• Dry erase board or flipchart, and markers (optional)
• Reading resource*s*

Teacher Note:

*There are **(2)** different versions of this simulation. Depending on which method you choose, your Materials List will differ for this Module. Links to the System Dynamics Society and MIT Sloan School of Management provide information about both simulation methods.

Investigating Sustainable Resource Management Using the Fish Banks Simulation

Summary

Module 2, *Investigating Sustainable Resource Management Using the Fish Banks Simulation*, allows students to understand the economic challenges of commercial fishing and sustainable harvesting of a resource.

> *This game about marine fisheries is based on a computer model developed through application of a systems analysis technique called System Dynamics* (SD), http://www.systemdynamics.org/what-is-s/. *System Dynamics is a comprehensive approach to representation, diagnosis, and change of behavior patterns in complex dynamic systems. The SD method is based on concepts of information feedback, and it employs computer simulation of feedback models representing real world issues.*[1]

Fish Banks is an interdisciplinary, multiplayer, role-playing program that simulates the commercial marine fishing industry, and illustrates how wise management of renewable natural resources can provide food (or other basic necessities) for human consumption now and for the future.

To clarify, the name of this simulation may be confusing. The original board game was referred to as Fish Banks, Ltd. MIT refers to its online simulation as Fishbanks. For the sake of consistency, we will refer to both versions in this Module as Fish Banks.

In the simulation, students play the role of fishing companies. Their goal is to maximize their net worth as they compete against other players, and deal with variations in fish stocks and their catch. Participants buy, sell, and build ships; decide where to fish; and negotiate with one another. Policy options available to simulation instructors include auctions of new boats, permits, and quotas. (Sterman and King, 2013)

As the simulation proceeds, fishing companies often begin competing to maximize their assets. Although the term **competition** is *never* directly stated by the instructor, it is subtly implied. At various times during the simulation, the instructor may announce which teams are in 1st, 2nd and 3rd places based on the value of total assets. As the competition increases, teams often forget to think of the fishery resource as an important component of the system. When the fishing pressure exceeds carrying capacity of the fish population, the resource eventually crashes. Unfortunately, by the time they realize that the fish population is at risk, it is often too late to change their company strategies, and fishing "behavior," and the fishery is no longer a viable industry/resource.

The debriefing activity at the end of the game helps to explain what happens in a system when the carrying capacity of the system exceeds its limits. The debriefing will also include examples of Chesapeake Bay resources with similar challenges, a discussion of management issues facing the Eastern oyster, and how the simulation relates to oyster management. (You may also refer back to **Module 1** that focused on problems associated with historic oyster management).

Background

A renewable resource is a resource that can be harvested or used without completely depleting, damaging, or destroying it. If managed responsibly, it can be renewed at the same rate it is being used (e.g., water, timber, wild game, fish, soil).

> **Teacher Note:** Click on the link, https://fitz6.wordpress.com/2016/01/14/renewable-and-non-renewable-resources/. Here you will see a chart that identifies renewable and nonrenewable resources. The chart breaks down the different types of resources, and is detailed and clear. Check out more links on this page; the site offers a wealth of resources, and can provide you and your students more background information about this topic.

Nonrenewable resources are finite inorganic resources found within the Earth that are extracted by various means of technology, such as mining or hydraulic fracturing. They are *finite* in that new sources of these types of resources (e.g., fossil fuels and minerals) will not be replaced with new sources within our lifetime. They originated as organic material (decaying plants and animals), and with heat and pressure over millions of years became valuable resources that we now use to create products (or components of products), heat homes, fuel vehicles, etc.

NOAA and Sustainable Fisheries

Chesapeake Bay fisheries play a critical role in the culture, economy, and ecology of the region. NOAA works to promote ecosystem-based management of fisheries and supports modeling, monitoring, and research to help identify the most important factors influencing the fisheries of the Chesapeake Bay.

NOAA science and research help decision makers manage several key species. These species are ecologically and economically important for the Chesapeake Bay, and include Atlantic menhaden, blue crabs, striped bass (rockfish), alosines (e.g., shad and herring), and oysters. The Chesapeake Bay Program, http://www.chesapeakebay.net/, provides more information about these species.

Sustainable fisheries are an important objective for many federal and state agencies. The Chesapeake Bay Program's Sustainable Fisheries Goal Implementation Team, http://www.chesapeakebay.net/groups/group/sustainable_fisheries) is composed of the state fisheries managers from around the Bay drawing together a diverse group of managers and scientists to improve management and recovery of key fisheries species. The team is working to apply ecosystem-based management practices that encourage sustainable Chesapeake Bay fish populations, support viable recreational and commercial fisheries, and provide for natural ecosystem function.

The groups within the Fisheries Goal Implementation Team include the following teams:

- Chesapeake Bay Stock Assessment Committee
- Fish Habitat Action Team
- Forage Action Team
- Invasive Species Task Force
- Maryland and Virginia Oyster Restoration Interagency Teams

There is a need for connecting fishery stock assessments to habitat, climate, and multispecies factors that influence fish populations and sustainability. NOAA also works with the Fisheries GIT to develop and evaluate scientific tools such as ecological assessments, models, and forecasts to improve resource management decision making in the Bay.

Fish Banks, Education, and Real World Scenarios

Fish Banks offers an interdisciplinary learning experience for students with strong connections to environmental science, social science, technology, math, and English/language arts education standards.

Since its creation, the Fish Banks simulation has been played by a very diverse audience. It has been used in colleges, universities, and 5th-12th grade classes worldwide. Additionally, Portugal's Ministry of Natural Resources, agricultural officials in New England, and senior United Nations officials, have all participated in the Fish Banks simulation.

After the debriefing, the majority of these players have reported lessons they learned from the game greatly clarify the nature and longer term implications of the economic and biological forces that have led to steady deterioration of the globe's fisheries and other renewable resources. (Meadows, Fish Banks Game Administrator's Manual, 2004)

There are many real world implications to the systems thinking model that are employed by the Fish Banks simulation. Local examples of how successful management of a resource can change the direction of a declining population include the Atlantic Coast striped bass, also referred to as *rockfish*, and the Canada goose. From 1985-1990, a moratorium was placed on the rockfish (https://www.fws.gov/Chesapeakebay/striper.html). This strict regulation was difficult for the commercial fishermen and businesses that support them, but the striped bass population rebounded after 5 years, and is considered a success story. Another example of how strict management was necessary for was for the Canada goose in the Mid-Atlantic Flyway. A 6-year moratorium was placed on the Mid-Atlantic Canada goose population where regulations did not allow hunting of the species from 1995 through the 2000-2001 hunting season. The Canada goose moratorium yielded similar results as the rockfish moratorium. (See Sun Paper Article, http://www.bayjournal.com/article/migratory_canada_goose_season_remains_closed_for_4th_year).

What is important to note here, is that the Fish Banks simulation can be used to reflect many sustainable resource dilemmas, not just problems related to fisheries management issues. Playing the game and analyzing the human impacts on the fishery is easily compared to other sustainable resource management problems, such as oyster management. Understanding the interaction of social and ecological systems is critical to understanding environmental issues, and developing solutions to solve or mediate environmental problems.

Summary of Fish Banks Game Play Steps

Fish Banks is played in three steps:

- **Role Description** – Introduction to the game in which participants learn about the goals of the game, the factors that affect team success and the initial conditions of the game, which includes the number of boats and the amount of money each team begins with.
- **Game Play** – This covers a number of "fishing seasons" or rounds of the game, where the teams must make decisions about increasing the number of ships in their fleet, and allocating what areas they wish to work their ships.
- **Debriefing** – Following completion of the game, participants are debriefed on what occurred during play. Fish Banks provides many examples of real world resource management scenarios, but you can find Chesapeake Bay debriefing slides in APPENDIX D.

Learning Objectives

- Students will be able to explain the difference between renewable and nonrenewable resources, the meaning of sustainable use of these resources, and discuss how these resources are used by society.
- Students will use a computer simulation that models carrying capacity, and explores the concept of sustainable harvest of renewable resources.
- Students will analyze data from the computer simulation (game behavior), and analyze changes that could promote sustainable resource use.
- Students will examine how the simulation models carrying capacity of the fishery, and the interaction of environmental, economic, and social systems.
- Students will identify underlying causes of behavior and limiting factors that contributed to the decline in the fishery.
- Students will analyze the causes and effects of overexploitation of resources.
- Students will use literature to draw comparisons between the Fish Banks simulation, and the oyster management issues, both historic and current, using the principles of a *Tragedy of the Commons* to demonstrate understanding of the complexity of environmental issues.

Essential Questions

- What is the distinction between renewable and nonrenewable resources? What does it mean to manage resources sustainably?
- How does human activity affect natural systems?
- How do management policies contribute to resource protection, restoration, or depletion?
- How do we manage natural resources, while maintaining economic and ecological viability?
- How does communication and the act of negotiation/collaboration benefit resource management decisions?

Key Words

Carrying Capacity – the maximum number of individual organisms that a habitat or a region can support before environmental degradation or social stress takes place.

Commons – a general term referring to the cultural and natural resources accessible to all members of a society, including natural materials such as air and water. The Chesapeake Bay is a commons.

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

Non-Renewable Resource – a resource that is limited in quantity

Population Dynamics – how the number of individuals of the same species in a population changes over time.

Recruitment – the addition of new individuals to a population by reproduction, commonly measured as the proportion of young in the population just before the breeding season.

Renewable Resource – any natural resource that can replenish itself naturally over time; a resource that can be renewed at the same rate it is being used, if managed responsibly (e.g., water, trees, waterfowl, fish, shellfish, soil, etc.); a resource that can be harvested or used without completely depleting, damaging, or destroying the resource.

Sustainability – maintaining an ecological balance by avoiding depletion of natural resources.

System Dynamics – a computer-aided approach to policy analysis and design that applies to dynamic problems arising in complex social, managerial, economic, or ecological systems.

Sustainability – maintaining an ecological balance by avoiding depletion of natural resources.

System Dynamics – a computer-aided approach to policy analysis and design that applies to dynamic problems arising in complex social, managerial, economic, or ecological systems.

Systems Thinking – focuses on how things interact with other components in the system (a set of elements that interact to produce behavior) of which it is part.

Vocabulary Sources:

Human Impacts on Ecosystems – Richmond School District, British Columbia, Canada
http://public.sd38.bc.ca/~cbebluk/humanimpactsonecosystemsprocess.html

How Do Humans Use Resources and What Are the Environmental Impacts?
http://slideplayer.com/slide/9821779/

KQED Science
https://ww2.kqed.org/quest/2014/02/13/nonrenewable-and-renewable-energy-resources-2/

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

ACTIVITY I: Are These Resources Renewable?

ENGAGEMENT/EXPLANATION

Students will be able to explain the difference between renewable and nonrenewable resources, the meaning of sustainable use of these resources, and discuss how these resources are used by society.

1. Determine what your students know about renewable natural resources by having them complete, *Are These Resources Renewable*? Teacher Pages can be found in APPENDIX A, and Student Pages can be found in APPENDIX B.

2. Upon completion, review their work in a class discussion.

3. What does the term *sustainable* mean, and how does it apply to both renewable and nonrenewable resources? How are the resources that are listed used by humans? (e.g., food, building materials, energy sources, etc.)

4. Are things that we can do to ensure the sustainability of natural resources?

Teacher Preparation

Teacher preparation is critical to successfully operating the simulation with your students. Review the Teacher Preparation pages that follow. Here you will find separate sections summarizing the Materials and Steps of Play for each version of the simulation. These sections are labeled as follows:

    A. Fish Banks Game Kit

- Materials Summary
- Steps of Play Summary

    B. Fish Banks – MIT Learning Edge (online)

- Materials Summary
- Steps of Play Summary

For a *detailed* side-by-side comparison of the Game Kit and Online Fish Banks Simulations, go to APPENDIX C. The Appendix also provides the *Table of Contents* for each simulation, which will afford you more details.

> **Detailed procedures for this simulation are *not* found in this Module. Clear step by step procedures are provided in *both* Fish Banks game version Training Manuals.**

Fish Banks Game Kit – Materials Summary

http://www.systemdynamics.org/products/fish-bank/

- A computer is required for the instructor.
- Fish Banks Game Board
- 85 Wooden Boats
- FishBanks Version 8.0 CD – Game Software and Electronic Files
  - o Introductory Video by Dennis Meadows (Mac or Windows format, ~13:22 min). The presentation includes information about the following:
    - Team Roles
    - Team Goals
    - Financial Information – income and costs
    - Fishing Fleet
    - Catch and Ship Effectiveness
    - Fishing Areas
    - Fish Population and Regeneration
  - o Debriefing Presentation – video format
  - o Various data files
  - o (2) PowerPoint slide sets – one for introducing the game (an alternative to the above video) and one for debriefing the game
  - o 48 page e-manual for download. The e-manual contains *extensive* information on setting up, introducing, conducting, and debriefing the game plus detailed instructions for operating the computer program.

Optional: Create your own Chesapeake Bay Game Board

Change the fishing locations from Deep Sea and Coastal areas to Coastal, and use Delaware Bay as your Harbor. On the Decision Sheet, you will have to change the Deep Sea to Chesapeake Bay/Tributaries; just be careful transcribing the numbers, or you could create a new Decision Sheet that reflects the changes.

Teacher Note: The game administrator (teacher) should read the manual carefully, and pay close attention to the introductory video. One should also practice playing the game *prior* to playing with their students. *The Fish Banks Game Kit Teacher Manual - Table of Contents* can be found in APPENDIX C.

Fish Banks Game Kit – Steps of Play Summary

The *Steps of Play* covers a number of "fishing seasons" or rounds of the game, where the teams must make the following decisions:

- Record data from computer printout
- Collect ships and money
- Bid for auctioned ships
- Buy or sell ships in trading session
- Place orders for new ship construction
- Calculate and record fleet size
- Allocate ships among fishing areas and harbor, and record on the decision sheet
- Place ships on the game board
- Give decision sheet to the computer operator
- Develop your strategy for ending the game with the maximum possible assets. (This will be performed every (3) years or fishing rounds).

The Simulation ends when there are little or no fish left to catch.
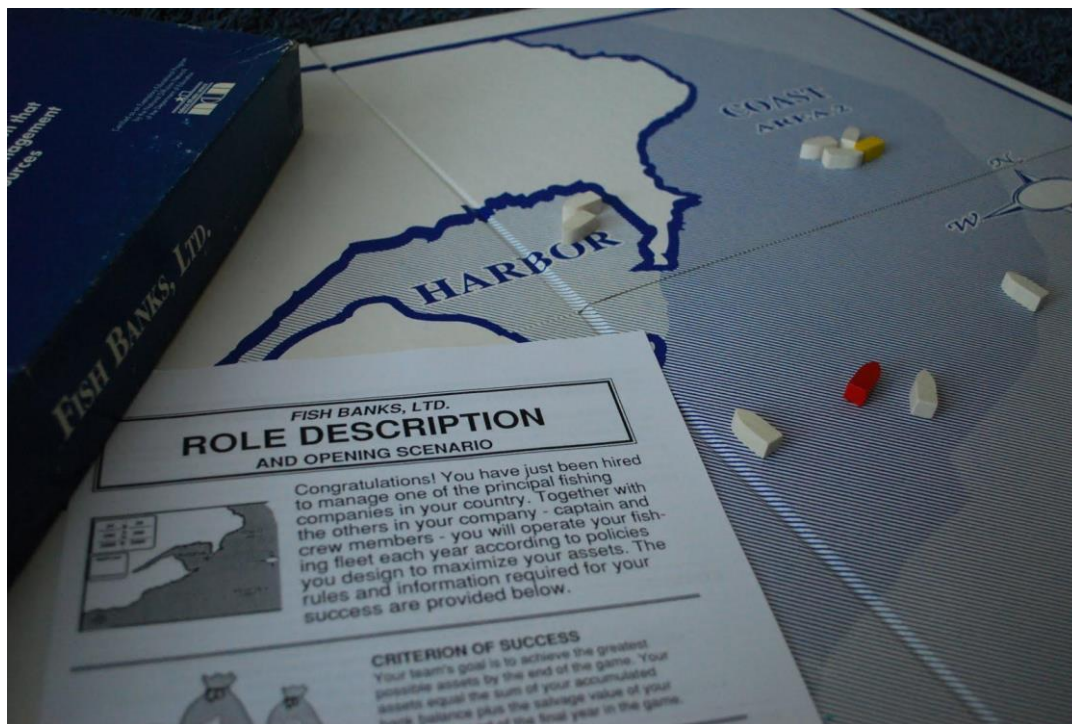
Photo Source: System Dynamics Society, http://www.systemdynamics.org/products/fish-bank/

Photo Source: System Dynamics Society, http://www.systemdynamics.org/products/fish-bank/

Teacher Note: The *Creative Learning Exchange Newsletter* provides a nice simple overview of Fish *Banks for 5th - 12th grade educators*, http://static.clexchange.org/ftp/newsletter/CLEx24.2.pdf. A summary of the lesson contents can be found in APPENDIX C.

Optional: Another potential option for using the simulation would be to combine elements from both of the methods described above. By including the game board, boats, and money with the online simulation, you provide more hands-on elements for students and a varied learning experience.

B. FISH BANKS ONLINE SIMULATION (MIT) – Materials and Steps of Play

Fish Banks Online Simulation (MIT) – *Materials Summary*

- **Computers** for each team of 2-4 students; **computer** for instructor
- You must first **REGISTER** as an Educator before you can access the online materials, including a Teaching Video and Teaching Guide (PDF).
- Go to the MIT Sloan Learning Edge site to begin. https://mitsloan.mit.edu/LearningEdge/simulations/fishbanks/Pages/fish-banks.aspx
- Click on Educator Register at the top right portion of the screen in the *screen capture* below.

Photo Source: MIT LearningEdge, https://mitsloan.mit.edu/LearningEdge/simulations/fishbanks/Pages/fish-banks.aspx

- Once you receive a login and you set up your password, you can set up a class as an Administrator. http://forio.com/simulate/mit/fishbanks/simulation/login.html
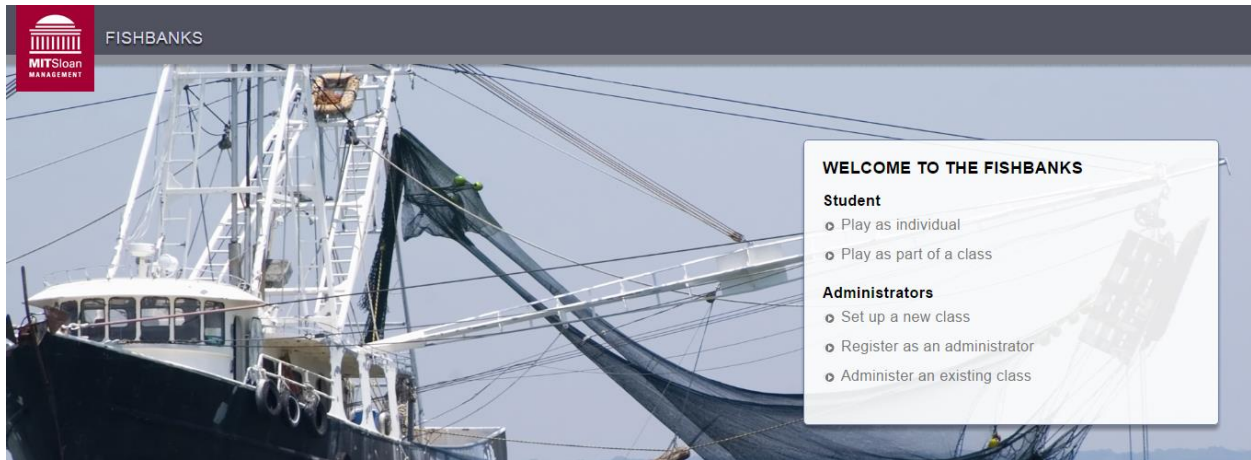

Photo Source: MIT LearningEdge, https://mitsloan.mit.edu/LearningEdge/simulations/fishbanks/Pages/fish-banks.aspx

- When you are *registered*, you can access all of the Fish Banks Materials shown in the screen shot below:

Teacher Note: Teachers may be interested in using the *Fish Banks Simulation Teaching Guide for K-12 Education* as seen on the screen shot above. The actual Teaching Guide and simulation are appropriate for 5th-12th grade.

This lesson targets different Learning Standards than the NOAA Oyster High School Unit, which has a special focus on Life Science, although there are Earth System Science applications throughout the NOAA K-12 Learning Sequence.

On page 1 of this Training Guide it indicates that the Team Goal is to, "*Manage a fishing company, maximizing its total assets while* **competing** *with other companies that are working toward the same goal*." Remember not to tell your students this is a competition!

Student Screen

Fish Banks Online Simulation (MIT) – *Steps of Play Summary*

The *Steps of Play* covers a number of "fishing seasons" or rounds of the game, where the teams must make the following decisions:

- Initial fishing company data is available online in the game simulation; students enter their decisions into the computer, rather than on a paper decision sheet.
- Bid for auctioned ships – live or Web-based
- Buy or sell ships in trading session
- Place orders for new ship construction
- Allocate ships among fishing areas and harbor
- Update decisions

End of Teacher Preparation Section

ACTIVITY II: Playing Fish Banks – Briefing and Game Play

EXPLORATION

Students will use a computer simulation that models carrying capacity, and explores the concept of sustainable harvest of a renewable resource.

1. Before beginning with the rules and steps of play, the teacher should explain the purpose of the game. All of the information the teacher needs can be found in the materials provided by both versions of the simulation – the Fish Banks Game Kit or the online simulation on the MIT Learning Edge Website.

2. Explain to the students that they will be participating in a group computer simulation that has been played with different kinds of audiences from all over the world. (See the Fish Banks Game Materials for more information about the history of the game). It has been used to illustrate the complex interactions and overlap of systems. In this particular case, we are looking at the interactions between environmental, social, and economic systems.

   The simulation applies cause-effect mechanisms that occur in renewable resource systems. Students participate in a role (fishing company) that allows them to experience the economic challenges of commercial fishing and sustainable harvesting of a resource. While we focused on oysters in Module 1, this simulation could represent any renewable resource, including oysters; however, in this activity the focus is on commercial fisheries in general.

3. Introduction to Fish Banks

   - Game Kit – Divide your students into teams/*fishing companies* of 3-5 players per team. Seat each team together at one table; three (3) to six (6) teams is the optimal number of teams. Each team will need a Decision Sheet, Ships, and Money.

   - MIT Learning Edge – Divide your students into teams/*fishing companies* of 2-4 players per team. Seat each team together at one table. Each team will need a computer.

4. Ask them to read the 6-page *Role Description*, and/or watch the Introductory Video. Both the Role Description literature and video will describe how the game is played. After they have completed this step, use the *Fish Banks Briefing Slides* to go over the remaining steps of play with your class.

   Teacher Note: To save time, have students read the *Role Description* as a homework assignment, and go over with the class as a group before initiating play.

5. Students will create a company name and logo for their fishing company, and share with their classmates. Display the company name and logo at each table.

6. **Playing the Fish Banks Simulation** – Follow the detailed *Steps of Play* in the *Game Administrator Resources* provided for either simulation.

Teacher Note: Beginning here, both game versions will follow the same procedure for the *Debriefing*.

ACTIVITY III: Fish Banks Debriefing – Student Insights

EXPLANATION/ELABORATION

Students will evaluate their experience playing the simulation, including insights and challenges that they encountered in a class discussion. They will then analyze data from the computer simulation (game behavior), and analyze changes that could promote sustainable resource use. Lastly, they will evaluate how the simulation models carrying capacity of the fishery, and how environmental, economic, and social systems interact.

Hold a class discussion where students share their experience playing the game. The following questions can be found in APPENDIX B: Student Pages.

1. How did the employees in your company work together? Did everyone on your team have an active role?

2. Was there collaboration among companies developed over time, or was the game driven by competition?

3. Did you notice declines in the catch over time? If so, did you negotiate with other companies to regulate the harvest at that time?

4. How did weather affect your catch each year?

5. If the goal of the game was to maximize your assets, did you consider how the fishery was an important component of the system?

6. Discuss your company's strategies while playing the game for years 3, 6, and 9.

   a. How did your strategies/decisions affect the fish populations?

   b. Did strategies change when, or if you noticed a decline in the fishery? Why?

   c. Did other companies have similar or different strategies? Did one strategy seem more effective than another? Explain.

7. How did your personal beliefs and values compare to that of the team as a whole during the game? Was there any internal struggle for you personally?

8. Did any of the companies "win" the game? Why or why not?

9. If you could play the simulation over again, what would you do differently?

ACTIVITY IV: Debriefing Fish Banks – Analyzing the Data

ELABORATION

Students will analyze Fish Banks "Game Behavior" by graphing the number of fishing boats, population of fish, and the number of fish caught using data derived by the computer program.

1. Watch the Debriefing video or PowerPoint presentation. Discuss as a class.

2. Using the data recorded from the game, students will graph the expansion of the fleet, and the catch over time.

3. What were the limiting factors affecting carrying capacity for this simulation? (Number of ships, ship effectiveness, and weather)

4. Identify other limiting factors that may not have been included in the Fish Banks simulation, but affect the fishery in a natural system.

Teacher Note: See Limiting Factors Diagram at
http://image.slidesharecdn.com/sci14bioeptx0502-140917092101-phpapp01/95/preap-bio-52-3-638.jpg%3Fcb%3D1410945714

The *Limiting Factors Student Page Template* can be found In APPENDIX B. Have them work individually or with their team to identify limiting factors of the fishery in the simulation. Are there any real world limiting factors they can identify in addition to ones they identified in Fish Banks.

- Competition, Predation, and Parasitism and Disease are *Density Dependent* Limiting Factors.
- Natural Disaster and Unusual Weather are *Density Independent* Limiting Factors

Weather was one of the variables that changed from year to year in the simulation. Note the Causal Loop Diagrams in the Game Administrators Guides.

4. Watch "What Happened to the Grand Banks Cod?" (YouTube Video) https://www.youtube.com/watch?v=L5wR8Iu2Q00, or "Who Killed Crassostrea virginica? The Fall and Rise of Chesapeake Bay Oysters," (YouTube Video Trailer, 3:19 min.) https://www.youtube.com/watch?v=6SLCOG2IB9k&feature=youtu.be The movie is available for sale.

5. How does the Fish Banks game behavior compare to current fisheries management problems? http://www.fldoe.org/core/fileparse.php/7662/urlt/0071787-limitsyourspecies.pdf

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ACTIVITY V: Debriefing Fish Banks – Stakeholder Beliefs and Values

EVALUATION

Students will identify underlying causes of behavior and limiting factors that contributed to the decline in the fishery.

1. Ask students if any specific *environmental events, problems, or issues* could be identified during their Fish Banks role-playing experience.

2. Ask students to share their strategies while playing the game. How did their strategies/decisions affect the fish populations? To what extent did they take into account the fishery while they were playing the game?

3. How did *stakeholders, beliefs, and values* play into the game, and how did it affect the decisions they made? (How did their beliefs and values as owners of a fishing company compare to articles they read regarding the oyster industry and the beliefs and values held by actual watermen?)

4. Systems Thinking: Using the causal loop diagram in the Fish Banks Debriefing Slides, explain the causal loop structure of the oyster system. How has technology altered this process?

5. As a group, brainstorm a list of ideas that would result in changing the undesirable aspects of game behavior. How would these solutions be applied in real systems? What are the difficulties in developing and implementing these changes?

    a. Analyze Fish Banks Game Behavior by graphing the number of fishing boats, population of fish, and the number of fish caught using data derived by the computer program.

    b. Determine the extent to which the same problems and events also occur in the real system by comparing the simulation to the management of the Eastern oyster in Chesapeake Bay.

    c. Decide what factors in the game were responsible for those problems, and determine the extent to which those factors are also present in real systems.

    d. Indicate the corresponding changes that could be made in real systems.

e. Ask students how they would commit to management solutions with competing fishing companies or other stakeholders to change the outcome. What actions would they take?

f. Identify possible solutions to reversing the declining trend of oysters, or other fisheries in the Chesapeake Bay.

g. If time allows, play the game again to assess what students have learned. What changes in game behavior would avoid or solve the most serious problems?

h. Read *Oyster Restoration Debate Rages on in Maryland* in the <u>Bay Journal</u>, <u>http://www.bayjournal.com/article/oyster_restoration_debate_rages_on_in_maryland</u>.

In the article, Matt Pluta, the Choptank Riverkeeper, spoke in favor of continuing oyster restoration in the Tred Avon River. (Construction had been suspended in the fall of 2015, <u>http://www.bayjournal.com/article/corps_agrees_to_delay_md_oyster_restoration_warns_of_funding_risk</u>, after watermen argued that sanctuaries were failing to meet intended goals of restoration).

Pluta stated, "Short-term economic gains should not overshadow long-term ecological benefits, which we are trying to achieve here."

How would this statement apply to the Fish Banks simulation?

Teacher Note: How does it apply to Activity VI: *The Tragedy of the Commons*, below?

i. Review the diagram, *Ecosystem Considerations, Measures, and Influences*, at <u>http://www.nwfsc.noaa.gov/publications/tm/tm184/tm186.pdf</u> *(Figure 32)* from NOAA Technical Memorandum NMFS-NE-184

Source: Gable, Frank J. (August 2004). A Large Marine Ecosystem Approach to Fisheries Management and Sustainability: Linkages and Concepts towards Best Practices. NOAA National Marine Fisheries Service, Northeast Fisheries Science Center, p. 50.

What management policies for sustainability guide decision-making for fisheries resources?

ACTIVITY VI: Debriefing Fish Banks – Tragedy of the Commons

EVALUATION

Students will use literature to draw comparisons between computer models, real world resource sustainability issues, and the complexity of, and interaction between human and biological systems.

1. *The Tragedy of the Commons*, by Garrett Hardin, was published in the Journal, *Science*, in 1968, http://www.sciencemag.org/content/162/3859/1243.full. Hardin discusses how a *Commons* will ultimately fail if all of those using the commons do not recognize their combined effects on the resource and the overall system, or on the integration of systems.

   Have students read the essay, and engage in one of the following activities:

   a. Write an essay comparing *The Tragedy of the Commons* to oyster management during the Oyster Wars from **Module 1** or a current Chesapeake oyster management issue.

   b. Divide students into groups, where they take a position on oyster management, and argue their position in class with their peers based on evidence from Hardin's essay, news articles, and the Fish Banks simulation.

ACTIVITY VII: Comparing Both Sides of the Issue – *The Lorax* and *Truax*

EXTENSION

Students will use literature to evaluate both sides of an issue related to sustainable resource management.

1. Students will read *The Lorax* by Dr. Seuss, or watch *The Lorax* as a class on YouTube, https://www.youtube.com/watch?v=FSSrYnc1yQs.

   a. Write an essay that compares the environmental issue in the book to that of the game played today; or, compare *The Lorax* to the Eastern oyster.

   b. Using the *Causal Loop Diagram* from the *Debriefing*, develop a causal loop depicting the behavior observed in *The Lorax*. (See the manual provided in the *Debriefing Slides,* or the *Systems Thinking* resources at the end of the Unit for more information).

   c. Ask students to read *Truax*, http://woodfloors.org/truax.pdf, the National Wood Flooring Association's response to The Lorax. (It can be downloaded). Compare the beliefs and values in both stories.

   d. What were the events, problems, and issues?

   e. Who were the stakeholders, and what were their beliefs and values.

   f. Ask students to write their own children's story about over-harvesting of a resource they value.

2. Have students read, Rosenberg, et al (5 November 1993). *Achieving Sustainable Use of Renewable Resources*, Science, Volume 262, pp. 828-829. http://www.sciencemag.org/site/feature/data/sust/pdf/262-5135-828.pdf

a. If sustainability is the goal of renewable resource management, what management practices have been used in the Chesapeake Bay region to maintain species populations?

b. Choose a species to research, and investigate management practices for that species. Write a brief summary of your investigation. Can you identify events, problems, and issues associated with species management?

Teacher Note: The Fish Banks materials provide some of the following suggestions to conserve and protect species from overharvesting:

- Limiting the season, technology/equipment, and catch limits
- Taxing effort
- Restricting fishing areas
- License fees

Other References

A Short History of Commercial Fishing in the Chesapeake Region
http://dnr2.maryland.gov/fisheries/Documents/history_of_comm_fishing.pdf

NOAA Chesapeake Bay Office – Fish Facts, Oysters
http://chesapeakebay.noaa.gov/fish-facts/oysters

Fish Banks Credits:

LaVigne, Anne. (2015). FishBanks Lesson Guide and Handouts for 5th-12th grade audience. Creative Learning Exchange, http://static.clexchange.org/ftp/newsletter/CLEx24.2.pdf

FishBanks, Ltd. game originally developed by Dennis Meadows, Emeritus Professor of Systems Management, University of New Hampshire.

Web version developed by Professor John Sterman (MIT Sloan School of Management), with help from Prof. Andrew King (Tuck School of Business), Dennis Meadows, Keith Eubanks, and Forio.com. Available from
https://mitsloan.mit.edu/LearningEdge/simulations/fishbanks/Pages/fish-banks.aspx

Game Kit screen shots from System Dynamics Society.

Simulation screen shots from web version of FishBanks.

EDUCATION STANDARDS

NGSS - *Disciplinary Core Ideas*	**HS-LS2.A: Interdependent Relationships in Ecosystems**	*How Standard is Addressed -*
	Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving 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 (number of individuals) of species in any given ecosystem.	**HS-LS2.A: Interdependent Relationships in Ecosystems** In this activity, students are able to differentiate between renewable and finite resources, and experience, through a computer simulation, how wise management of natural resources helps maintain a balanced population, and that over harvesting can exceed the carrying capacity of the population.
	HS-LS2.C: Ecosystem Dynamics, Functioning, and Resilience Anthropogenic changes (induced by human activity) in the environment – including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change – can disrupt an ecosystem and threaten the survival of some species. (*HS-LS2-7*)	**HS-LS2.C: Ecosystem Dynamics, Functioning, and Resilience** Building on Module 1, where students read about historic overharvesting of oysters, here students participate in a simulation and role playing activity to illustrate how overharvesting can deplete the resource, and threaten its survival.
	LS4.D Biodiversity and Humans 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 overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus, sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to	**LS4.D Biodiversity and Humans** Through the Debriefing of the Fish Banks simulation, students learn how social systems can adversely affect biological systems. Oysters are important economically as a source of food for humans. Loss of

NGSS - Disciplinary Core Ideas	supporting and enhancing life on Earth. (secondary to LS2.C) **HS-ETS1.B: Developing Possible Solutions** Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as *running simulations* to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. (*secondary to HS-LS4-6*)	the oyster industry would adversely affect those who make their living harvesting oysters. **HS-ETS1.B: Developing Possible Solutions** After the Debriefing, and additional readings (*Tragedy of the Commons* and *The Lorax*), students play the simulation again to maintain the population and succeed as an industry, if managed responsibly.
NGSS - Science and Engineering Practices	**Using Mathematics and Computational Thinking** Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. - Use mathematical and/or computational representations of phenomena or design solutions to support explanations. (*HS-LS2-1*) - Use mathematical representations of phenomena or design solutions to support and revise explanations. (*HS-LS2-2*) - Create or revise a simulation of a phenomenon, designed device, process, or system. (*HS-LS4-6*) **Constructing Explanations and Designing Solutions** Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.	**Using Mathematics and Computational Thinking** The Fish Banks computer simulation represents the fishery (biological system) and how the impacts of the economic pressures (social system) interact. During the Debriefing, students analyze the "game behavior" represented by: • # of fish in the population • # of ships • # of fish caught Students can change the outcome of the simulation by applying what they have learned through the Debriefing process. **Constructing Explanations and Designing Solutions** Students can change their strategies to regulate how the fishery is managed.

NGSS - *Science and Engineering Practices*	- Design, evaluate, and refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (*HS-LS2-7*) **Engaging in Argument from Evidence** Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in Science. - Compare, integrate, and evaluate sources of information presented in different media formats, as well as in words in order to address a scientific question or solve problem. - Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.	**Engaging in Argument from Evidence** Building on Module 1, and historic oyster harvests, students can argue that the Fish Banks simulation closely represents what happens in the real world. In addition to the computer role-playing simulation, these comparisons can be drawn from different sources and media formats, including scientific and technical papers, a children's book (*The Lorax*), a scientific essay (*The Tragedy of the Commons*), video and newspaper and articles, and presentations. These sources help students build on their existing knowledge and understanding of issues related to oyster popula-tions in Chesapeake Bay.
NGSS - *Crosscutting Concepts*	**Cause and Effect** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (*HS-LS2-8*) **Systems and System Models** Models can be used to simulate systems and interactions – including energy, matter, and information flows – within and between systems at different scales. (*HS-LS2-5*) **Stability and Change** Students understand much of science deals with constructing explanations of how things change and how they remain stable. They	**Cause and Effect** Cause and effect is represented when analyzing the game behavior. The number of fish caught increases with the number of ships fishing, which affects the fish population. **Systems and System Models** Fish Banks represents the interaction of two separate systems: biological and social/economic.

NGSS - Crosscutting Concepts	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.	**Stability and Change** In analyzing game behavior, students can also argue that fishing pressure changed the stability of the fish population over time if not recognized early enough during game play. At some point it may be too late to make management changes for the population to return to its previous numbers and stabilize.
Ties to Common Core	**ELA/Literacy** **RST.9-10.8:** Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem. (*HS-LS2-6*),(*HS-LS2-7*),(*HS-LS2-8*) **RST.11-12.7:** Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (*HS-LS2-6*),(*HS-LS2-7*),(*HS-LS2-8*) **WHST.9-12.2:** Write informative/explanatory texts, including narration of historical events. (HS-LS2-1, HS-LS2-2) **Mathematics** **MP.2:** Reason abstractly and quantitatively **MP.4:** Model with mathematics Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales. Emphasis is on quantitative analysis and comparison of the relationships among interdependent factors, including boundaries, resources, climate, and competition. Examples of mathematical comparisons could include graphs, charts, histograms, and population changes gathered from simulations or historical data sets.	**ELA/Literacy** *The Tragedy of the Commons* from the Journal, *Science*, *The Lorax* (Video-original; fiction), and the Chesapeake Bay oyster industry, both historic and current, are compared. Students will then develop solutions to address current oyster-related management issues. **Mathematics** Students are given data to create graphs depicting local fisheries resource harvests over time (NMFS NOAA), as well as game behavior data, which include the number of ships fished, ship effectiveness, and the number of fish caught.

MD Environmental Literacy Standards	**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. **Topic B.** Human Impact on Natural Resources **Indicator 1**. Analyze, from local to global levels, the relationship between human activities and the earth's resources	**Standard 5: Humans and Natural Resources** Students investigate how human activity (harvesting) of a local natural resource (Eastern oyster in Chesapeake Bay) affects the overall population using system dynamics as a tool that simulates this interaction.
	Standard 8: Sustainability The student will make decisions that demonstrate understanding of natural communities and the ecological, economic, political, and social systems of human communities, and examine how their personal and collective actions affect the sustainability of these interrelated systems. **Topic B.** Interconnectedness of Systems **Indicator 1.** Recognize the concept of sustainability as a dynamic condition characterized by the interdependency among ecological, economic, and social systems and how these interconnected systems affect individual and societal well-being.	**Standard 8: Sustainability** Using a computer simulated method that reflects how economic/ social systems interact; students make decisions about how their individual actions impact a natural community that is highly valued by humans. In the debriefing section of the activity, students analyze the game behavior (interactions between number of boats fishing, effects on catch, and the value of their assets as they strategized through-out the simulation). They make recommendations on what, if any, changes they would make in their strategies. They also look at real world examples of overharvesting of local natural resources, and compare it to their game experience.

MODULE REFERENCES

Anne Lavigne, Creative Learning Exchange, FishBanks Lesson Guide and Handouts for 5th-12th grade audience. http://static.clexchange.org/ftp/newsletter/CLEx24.2.pdf

Chesapeake Bay Program, http://chesapeakebay.net

Dennis Meadows by email and phone; Fish Banks, Ltd. Teacher Manual

Dr. Seuss. (1971). The Lorax. Random House: New York, NY.

John Sterman by email and phone; Fish Banks Simulation Guide

MD Department of Natural Resources, Maryland's Commercial Fisheries Annual Landings Data Set

MIT Sloan School of Management, https://mitsloan.mit.edu/LearningEdge/simulations/fishbanks/Pages/fish-banks.aspx

NOAA Chesapeake Bay Office – Fisheries, http://chesapeakebay.noaa.gov/fisheries/fisheries

NOAA National Marine Fisheries Service, Commercial Fish Landings

System Dynamics Society - Fish Banks Game Kit, http://www.systemdynamics.org/products/fish-bank/

The Tragedy of the Commons - Garrett Hardin, http://www.garretthardinsociety.org/articles/art_tragedy_of_the_commons.html

Truax, http://woodfloors.org/truax.pdf

ADDITIONAL RESOURCES

Curriculum
Global Systems Science, http://www.globalsystemsscience.org/

Systems Thinking in Schools, http://www.watersfoundation.org/webed/mod1/index.html

Data and Graphs
NOAA National Marine Fisheries Service, Commercial Fish Landings, http://www.st.nmfs.noaa.gov/commercial-fisheries/commercial-landings/annual-landings/index

Essays & Articles

An Assessment of the Educational Potential of a Fisheries Management Simulation Game for Environmental Sciences Students (23020_Ruiz et al_Educational potential of fishbanks_Proceedings Edulearn.pdf), https://repositorio.uam.es/bitstream/handle/10486/3188/23020_Ruiz%20et%20al_Educational%20potential%20of%20fishbanks_Proceedings%20Edulearn.pdf?sequence=1

Earth Resources: The Little Engine That Could Brake Sustainability, http://bcn.boulder.co.us/basin/local/sustain_update.html

They're back: The incredible resurgence of striped bass,
http://www.dnr.state.md.us/programs/nr/rockfish.html

The Tragedy of the Commons - Garrett Hardin,
http://www.garretthardinsociety.org/articles/art_tragedy_of_the_commons.html

Fisheries   Resources

Chesapeake Bay Program – Sustainable Fisheries Goal Implementation Team,
http://www.chesapeakebay.net/groups/group/sustainable_fisheries

Chesapeake Stat, http://www.chesapeakestat.com/

MD Sea Grant http://www.mdsg.umd.edu/
- Ecosystems-Based Fishery Management,
  http://www.mdsg.umd.edu/topics/ecosystem-based-fisheries-management/ecosystem-based-fisheries-management
- Blue Crabs, http://www.mdsg.umd.edu/topics/blue-crabs/blue-crabs
- Eastern Oyster, http://www.mdsg.umd.edu/topics/oysters/oysters
- Striped Bass, http://www.mdsg.umd.edu/topics/striped-bass/striped-bass
- Menhaden, http://mrc.virginia.gov/commercial.shtm

NOAA Chesapeake Bay Office
- Fish Facts - Oysters http://chesapeakebay.noaa.gov/fish-facts/oysters
- 2012 Blue Crab Advisory Report
  http://www.chesapeakebay.net/documents/CBSAC2012_Report_Figures.pdf
- Fisheries Science http://chesapeakebay.noaa.gov/fisheries/fisheries-science

NOAA Fisheries - Office of Science and Technology, NOAA Fisheries - Human Dimensions and
Fisheries, http://www.st.nmfs.noaa.gov/humandimensions/index

Virginia Marine Fisheries Commission, http://mrc.virginia.gov/commercial.shtm
- Virginia's Oyster Management Today,
  http://mrc.virginia.gov/VIRGINIAS_OYSTER_MANAGEMENT_AND%20_INDUSTRY_TODAY.pdf
- Virginia Watermen's Associations, http://mrc.virginia.gov/watermanassoc.shtm

Systems Thinking Resources

MIT Sloan School of Management Simulations and Tools
https://mitsloan.mit.edu/LearningEdge/simulations/Pages/Overview.aspx

- Climate Interactive – Tools, https://www.climateinteractive.org/tools/
- Clean Start: Simulating a Clean Energy Startup,
  https://mitsloan.mit.edu/LearningEdge/simulations/cleanstart/Pages/default.aspx

- Eclipsing the Competition: The Solar PV Industry Simulation, https://mitsloan.mit.edu/LearningEdge/simulations/solar/Pages/default.aspx

MIT Open Course (Self Study)
- System Dynamics Course Readings, http://ocw.mit.edu/courses/sloan-school-of-management/15-988-system-dynamics-self-study-fall-1998-spring-1999/readings/
- System Dynamics Assignments and Solutions, http://ocw.mit.edu/courses/sloan-school-of-management/15-988-system-dynamics-self-study-fall-1998-spring-1999/assignments/

Creative Learning Exchange, http://www.clexchange.org/

Creative Learning Exchange Resource List, http://static.clexchange.org/ftp/CLE%20Resource%20List%202015.pdf

Donella Meadows Institute, http://www.donellameadows.org/

Finding and Resolving the Root Causes of the Sustainability Program, http://www.thwink.org/sustain/glossary/SystemsThinking.htm

Fish Banks Game Blog Spot, http://fishbanksgame.blogspot.com/

Maryland Virtual High School of Science and Mathematics, http://mvhs1.mbhs.edu/

Mental Modeler, http://www.mentalmodeler.org/

Population Dynamics - Connecting Past, Present, and Future, http://www.clexchange.org/curriculum/complexsystems/populationdynamics/

System Dynamics Society, http://www.systemdynamics.org/products/fish-bank/

Systems Thinking - A Cautionary Tale *(Cats in Borneo - A True Story*), https://www.youtube.com/watch?v=17BP9n6g1F0

Systems Thinking in Schools - The Waters Foundation, http://watersfoundation.org/our-resources/

Multi-Media (YouTube Videos)
Cod: The Fish that Made New England | Pew, https://www.youtube.com/watch?v=cLE56imBjJs

For Cod's Sake, https://www.youtube.com/watch?v=Zni6Iy5Q-Ko

The Lorax, https://www.youtube.com/watch?v=FSSrYnc1yQs

Serious Science: Biological Carrying Capacity, https://www.youtube.com/watch?v=QI2ixJeIxEU
State of the Planet's Oceans: Decimation of the Atlantic Cod Fishery https://www.youtube.com/watch?v=3fCX6XKzbUY

What Happened to the Grand Banks Cod? https://www.youtube.com/watch?v=L5wR8Iu2Q00

Who Killed Crassostrea virginica? The Fall and Rise of Chesapeake Bay Oysters, https://youtu.be/6SLCOG2IB9k

Newspapers, Periodicals, and Journals

Baker, Peter. (September 19, 1993). After successful five-year moratorium, it appears rockfish will be ready to roll, The Baltimore Sun. http://articles.baltimoresun.com/1993-09-19/sports/1993262169_1_fishery-striped-bass-spawning

Bay Journal, http://www.bayjournal.com/

Blue Crab population rebounds, http://ian.umces.edu/pdfs/ian_newsletter_286.pdf

Sustainability Resources

EPA - Learning About Sustainability,

http://www2.epa.gov/sustainability/learn-about-sustainability#what

Research, Sustainability, and Learning,

http://www.scoop.it/t/research-sustainability-and-learning

Sustainable Use of Renewable Resources, http://www.sciencemag.org/site/feature/data/sust/pdf/262-5135-828.pdf

Speakers

Aquaculture facilities

> Hooper's Island Oyster Aquaculture Company, http://www.hioac.com/

Local watermen

- Maryland Watermen's Association, https://marylandwatermen.com/index.html
- Maryland County Associations,

    https://marylandwatermen.com/county-associations.html
- Virginia Watermen's Association, http://www.mrc.virginia.gov/watermanassoc.shtm

Natural Resource Agencies

Field Trip Suggestions

Environmental Education Centers

- Phillips Wharf Environmental Center
    - o Fisheries Management Curriculum, http://pwec.org/programs/educational/fisheries-management-details/
    - o Aquaculture Education, http://pwec.org/programs/educational/aquaculture-education/

Hooper's Island Oyster Aquaculture Company, http://www.hioac.com/

Local Fish Markets or Seafood Houses

NOTE: For more field trip suggestions, visit **Bay Backpack** at http://baybackpack.com/field_studies/

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