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| The Ocean System |
| High School Biology & Earth and Space Science  (Revised July 2018) |
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| **Standards addressed in unit:**  **HS-LS2-2** Use mathematical representations to support explanations that biotic and abiotic factors affect biodiversity, including genetic diversity within a population and species diversity within an ecosystem.  **HS-LS2-6** Analyze data to show ecosystems tend to maintain relatively consistent numbers and types of organisms even when small changes in conditions occur but that extreme fluctuations in conditions may result in a new ecosystem. Construct an argument supported by evidence that ecosystems with greater biodiversity tend to have greater resistance to change and resilience.  **HS-LS2-7** Analyze direct and indirect effects of human activities on biodiversity and ecosystem health, specifically habitat fragmentation, introduction of non-native or invasive species, overharvesting, pollution, and climate change. Evaluate and refine a solution for reducing the impacts of human activities on biodiversity and ecosystem health.\*  **HS-ESS3-3** Illustrate relationships among management of natural resources, the sustainability of human populations, and biodiversity.  **HS-ETS1-3** Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, aesthetics, and maintenance as well as social, cultural, and environmental impacts.  In this integrated Biology/Earth Science unit, students will explore how physical, biological and geological features are intertwined in the ocean system, and how they are affected by humans. These concepts are explored via the lens of New England’s ocean system: The Gulf of Maine. In addition to integrating the disciplines of Earth Science and Life Science, the unit features Technology/Engineering and ELA as well as a strong focus on various science practices. |

*This Model Curriculum Unit is designed to illustrate effective curriculum that lead to expectations outlined in the 2016 Science and Technology/Engineering Curriculum Frameworks (*[*www.doe.mass.edu/STEM/STE*](http://www.doe.mass.edu/STEM/STE)*) as well as the MA Curriculum Frameworks for English Language Arts/Literacy and Mathematics. This unit includes lesson plans, a Curriculum Embedded Performance Assessment (CEPA), and related resources. In using this unit it is important to consider the variability of learners in your class and make adaptations as necessary.*

This document was prepared by the Massachusetts Department of Elementary and Secondary Education. Mitchell D. Chester, Ed.D., Commissioner

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*Resources for this unit are posted in a separate file on the Model Curriculum Units website (*[*http://www.doe.mass.edu/frameworks/mcu/*](http://www.doe.mass.edu/frameworks/mcu/)*, Ocean Systems (High School) Resources)*

# Unit Assumptions and Comments on Sequence

**Sequence:**

Following an introduction to the Gulf of Maine, students explore the 1) physical/chemical features of the Gulf of Maine and how they affect marine species, 2) the Gulf of Maine marine ecosystem and the interconnectedness of its components, and 3) human impacts on the ocean system. The unit provides students with an engaging and authentic way to learn about important concepts via an in-depth study of New England’s ocean resources. In addition, they have the opportunity to grapple with real-world problems currently facing New England’s marine resources, such as cod overfishing, habitat reduction due to invasive fishing methods, and reductions in key species due to bycatch.

**Assumptions:**

To be successful in this unit, students should already understand the concept of systems and ecosystems, as well as have experience crafting explanations (claims based on evidence, connected by reasoning) both orally and in written form.

Support for English Language Learners and Special Education Students

To support English Language Learners and Special Education students, we recommend that teachers:

* Use a wide variety of ways to explain concepts and assignments, such as using visuals (such as word walls, sentence frames, images, real objects, etc.) and supports such as graphic organizers. See the following links for descriptions of possible support options: <http://steinhardt.nyu.edu/scmsAdmin/uploads/004/739/NYU_PTE_Science_Module_For_ELLS_Oct_8_2009.pdf> and <http://www.misd.net/bilingual/ELL.pdf>.
* Frequently assess students for understanding (many formative assessment probes are included in the unit lessons).

**Notes to Teacher:**

* Due to the length of this unit, teachers may choose appropriate lessons depending on their desired content focus.
* In each lesson, an Instructional Notes to Teacher section is provided with ideas and strategies that may be used to help implement the lesson.
* Students should keep materials from lessons in a folder/binder for use in the Curriculum Embedded Performance Assessment (CEPA).
* Concept maps are used throughout this unit. For concept map background and information, see: 1) Kathy Schrock’s Guide to Everything, “Concept Mapping in the Classroom,” <http://www.schrockguide.net/concept-mapping.html> and 2) Gliffy ([www.gliffy.com](http://www.gliffy.com))
* Students should have access to their concept maps during the entire unit so they can revise/add to them. (The concept maps will act as visible tracks of their learning and thinking.)
* Throughout the unit, students will be asked to construct explanations (make claims based on evidence, connected by reasoning). For information on constructing explanations, see:” Designing Science Inquiry: Claim + Evidence + Reasoning = Explanation,” Edutopia, <http://www.edutopia.org/blog/science-inquiry-claim-evidence-reasoning-eric-brunsell>
* Science talks are featured throughout this unit and are important strategies for giving students the chance to rehearse their ideas, share their thinking, and think critically about the explanations of others. For information on facilitating science talks, see: Talk Science Primer, TERC (<http://inquiryproject.terc.edu/shared/pd/TalkScience_Primer.pdf>), Goals for Productive Discussions and Nine Talk Moves, TERC (<http://inquiryproject.terc.edu/assessment/Goals_and_Moves.cfm>),
* In Lessons, 3, 4, and 6, color copies of maps, satellite images, and other images will need to be printed out in advance. It is recommended that you laminate sets of these materials to prolong their use.
* **All Handouts/Readings/Visuals are listed at the end of the unit in the Unit Resources section. Listed unit handouts & resources are posted in a separate file on the Model Curriculum Units website** (<http://www.doe.mass.edu/frameworks/mcu/>, Ocean Systems (High School) Resources)

**Sources and Credits:**

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Other sources that were used to create this unit include:

* NOAA. Lesson 6: Ocean Layers I, <http://www.st.nmfs.noaa.gov/Assets/Nemo/documents/lessons/Lesson_6/Lesson_6-Teacher's_Guide.pdf>.
* COSEE. [www.cesn.org/cosee\_CD/web/activity/**Ocean**\_Satellites.pdf](http://www.cesn.org/cosee_CD/web/activity/Ocean_Satellites.pdf)
* *Exploring Satellite Images* by Amy Cline, <https://www.st.nmfs.noaa.gov/Assets/Nemo/documents/lessons/Lesson_12/Exploring_Sat_Images.pdf> ).
* NOAA’s National Marine Sanctuary Program and the National Geography Society. Exploring National Marine Sanctuaries lesson, <http://sanctuaries.noaa.gov/education>.
* PBS. Exploring National Marine Sanctuaries lesson (copy and paste link),

<https://mass.pbslearningmedia.org/resource/pbs_org14_jmcoa_sci_19/jean-michel-cousteau-ocean-adventures-lesson-plan-exploring-national-marine-sanctuaries/#.Wyu9nlKWzIU>

* PBS. How to Catch a Fish lesson (copy and paste), <https://mass.pbslearningmedia.org/resource/pbs_org14_jmcoa_sci_25/jean-michel-cousteau-ocean-adventures-lesson-plan-how-to-catch-a-fish/#.Wyu-P1KWzIU>
* NOAA. Empty Oceans lesson, <https://nmssanctuaries.blob.core.windows.net/sanctuaries-prod/media/archive/education/teachers/pdfs/sustain_seafood_lesson2.pdf>
* Massachusetts Marine Educators. Overfishing/Sustainable Fishing Activity, “Flotsam & Jetsam,” Spring 2010, Vol. 38, No. 4, : <http://ma-marine-ed.org/news-letter/quarterly-journal>.
* PBS Mathline. Something Fishy (copy and paste link), <https://mass.pbslearningmedia.org/resource/8581be38-522c-41cd-9422-87d48b0254cd/8581be38-522c-41cd-9422-87d48b0254cd/#.Wyu-kVKWzIU>
* California Academy of Sciences. Fishing for the Future, <http://www.pbs.org/emptyoceans/educators/activities/docs/Activity-Fishing.pdf>.
* NOAA Fisheries Service. Humans and Sturgeon: Great Debate, Scutes, , <http://www.nero.noaa.gov/prot_res/scutes/NewDocs/Debate%20-%20Humans%20and%20Sturgeon.pdf>.

See the strand map, next page, for an overview of the science standards that precede this unit and how the standards learned in this unit contribute to students learning in later grades.

Strand maps for standards HS-LS2-2, HS-LS2-6, HS-LS2-7, HS-ESS3-3, HS-ETS1-3.

HS-LS2-2
 - Prior standards: 7.MS-LS2-4, 7.MS-LS2-6(MA)
 - Following standards: HS-LS2-6

HS-LS2-6
 - Prior standards: 7.MS-LS2-4, 7.MS-LS2-6(MA), HS-LS2-2
 - Following standards: HS-LS2-7

HS-LS2-7
 - Prior standards: 7.MS-LS2-4, 7.MS-LS2-6(MA), 7.MS-LS2-5, HS-LS2-2, HS-LS2-6
 - Following standards: None

HS-ESS3-3
 - Prior standards: HS-ESS2-4
 - Following standards: None

HS-ETS1-3
 - Prior standards: 7.MS-PS1-4, HS-ETS1-1
 - Following standards: None

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| Unit Plan **Stage 1 Desired Results** | | |
| **ESTABLISHED GOALS**  **Ecosystems: Interactions, Energy, and Dynamics**  **HS-LS2-2** Use mathematical representations to support explanations that biotic and abiotic factors affect biodiversity, including genetic diversity within a population and species diversity within an ecosystem. Clarification Statements: Examples of biotic factors could include relationships among individuals (feeding relationships, symbiosis, competition) and disease. Examples of abiotic factors could include climate and weather conditions, natural disasters, and availability of resources. Examples of mathematical representations include finding the average, determining trends, and using graphical comparisons of multiple sets of data.  **HS-LS2-6** Analyze data to show ecosystems tend to maintain relatively consistent numbers and types of organisms even when small changes in conditions occur but that extreme fluctuations in conditions may result in a new ecosystem. Construct an argument supported by evidence that ecosystems with greater biodiversity tend to have greater resistance to change and resilience. Clarification Statement: Examples of changes in ecosystem conditions could include modest biological or physical changes, such as moderate hunting or a seasonal flood; and extreme changes, such as volcanic eruption, fires, the decline or loss of a keystone species, climate changes, ocean acidification, or sea level rise.  **HS-LS2-7** Analyze direct and indirect effects of human activities on biodiversity and ecosystem health, specifically habitat fragmentation, introduction of non-native or invasive species, overharvesting, pollution, and climate change. Evaluate and refine a solution for reducing the impacts of human activities on biodiversity and ecosystem health.\* Clarification Statement: Examples of solutions can include captive breeding programs, habitat restoration, pollution mitigation, energy conservation, and ecotourism.  **Earth and Human Activity**  **HS-ESS3-3** Illustrate relationships among management of natural resources, the sustainability of human populations, and biodiversity. Clarification Statements: Examples of factors related to the management of natural resources include costs of resource extraction and waste management, per capita consumption, and the development of new technologies. Examples of factors related to human sustainability include agricultural efficiency, levels of conservation, and urban planning. Examples of factors related to biodiversity include habitat use and fragmentation, and land and resource conservation.  **Engineering Design**  **HS-ETS1-3** Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, aesthetics, and maintenance as well as social, cultural, and environmental impacts.  **English Language Arts/Literacy**  **W.9-10.1** Write arguments (e.g., essays, letter to the editor, advocacy speeches) to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.  **W.11-12.1** Write arguments (e.g., essays, letter to the editor, advocacy speeches) to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence. | ***Transfer*** | |
| ***Students will be able to independently use their learning to…***   * Analyze systems by evaluating the roles of the individual components, how the components work together as a whole, and what happens when one or more components are altered | |
| ***Meaning*** | |
| **UNDERSTANDINGS**  ***Students will understand that…***   * The ocean system is made up of biotic and abiotic factors (physical, geological, and biological) that interact with each other and affect biodiversity. * If one component of the ocean system is significantly altered (extreme fluctuations occur), other components are affected as well, resulting in major changes in the ocean ecosystem. * Human activities have direct and indirect impact on the biodiversity and health of the ocean ecosystem. * Ocean system natural resources can be managed to reduce human impact, make the use of ocean resources by humans sustainable and maintain the biodiversity of the ocean system. * When designing solutions to the complex real-world problems faced by the ocean system, a wide range of prioritized criteria and trade-offs that account for a range of constraints need to be considered. * Claims must be supported by accurate and relevant evidence, and connected by logical reasoning. | **ESSENTIAL QUESTIONS**   * What are the components of the ocean system and how do they interact with each other? * How do humans impact the ocean system? * How can ocean resources be managed to reduce human impact, make the use of ocean resources by humans sustainable and maintain the diversity of the ocean system? |
| ***Acquisition*** | |
| ***Students will know….***   * The properties of ocean water, temperature, and the physical features of the ocean floor affect the geographic distribution of coastal and marine organisms. * Phytoplankton are the foundation of all ocean food webs. * Living and nonliving things in the ocean system are connected-if one component is altered, the others are affected. * Humans have significant impact on the ocean system’s health and biodiversity. * Solutions can be designed to address the complex problems facing the ocean system. The solutions need to consider a wide range of criteria and constraints. * Scientists and engineers make claims based on evidence (connected by reasoning) to create explanations to answer their questions. | ***Students will be skilled at….***   * Analyzing data to support explanations. * Using mathematical representations to support explanations. * Creating and using models to explain the relationships of system components. * Evaluating solutions to complex real-world problems. * Making and evaluating claims based on evidence (connected by reasoning) in writing (argument writing) and orally. * Synthesizing information. * Clearly communicating their ideas both orally and in written form. |
| **Stage 2 - Evidence** | | |
| **Evaluative Criteria** | **Assessment Evidence** | |
| **See CEPA Rubric** | **CURRICULUM EMBEDDED PERFORMANCE ASSESSMENT (CEPA)**    **Goal:** Synthesize what you have learned about the Gulf of Maine and clearly communicate (visually and orally) this summary with others. Communicate how important it is to take steps to save our valuable ocean system resources and empower middle school students to take action in their community  **Role:** Scientist  **Audience:** Middle school students  **Situation:** You have been hired to share information about the geology, physical features, and biology of the Gulf of Maine with the public in order to build awareness and increase protection of the Gulf of Maine’s marine resources.  **Product:** A digital story, presentation, or other product outlining what you have learned about the Gulf of Maine ocean system designed to share with middle school students. | |
|  | **OTHER EVIDENCE**   * Concept maps * Written explanations (claims based on evidence, connected by reasoning) * Hands-on investigation results and interpretations * Homework and blog posts * Projects and debates * Class presentations * Science notebook entries * Participation in Science Talks * Reflections on what students learned and how they learned it | |
| **Stage 3 – Learning Plan** | | |
| ***Summary of Key Learning Events and Instruction***  **Lesson 1: Introduction to the Gulf of Maine: New England’s Ocean System** *(Two 50-minute sessions)*  At the beginning of the unit, students are introduced to the Gulf of Maine, New England’s ocean system: its geography, geology, and marine life. After completing a pre-assessment, students read about the components of the Gulf of Maine system, create concept maps to describe what they learned, and participate in a class discussion.  **Lesson 2: Ocean Water’s Influence on the Distribution of Marine Organisms** *(Three 50-minute sessions)*  Students conduct investigations to explore how temperature and salinity affect the density of water and create layers in the ocean. These layers, in part, are a factor in the formation of ocean currents (which will be discussed in Lesson 3). Temperature and salinity also can affect the geographic distribution of marine organisms. Students explore how nutrients relate to productivity and how primary producers provide energy for ecosystems.  **Lesson 3: How Do Ocean Currents Influence Marine Organisms?** *(One 50-minute session)*  Students learn how the Earth’s ocean currents (horizontal and vertical) are affected by energy from the sun heating the Earth, the planet’s rotation, and wind. They analyze maps and apply what they have learned in previous lessons via class discussions. Ultimately, students extend their thinking to grapple with the question of how ocean currents influence the geographic distribution of marine organisms.  **Lesson 4: Using Satellite Data to Tell the Story of the Gulf of Maine** *(Four 50-minute sessions)*  Students extend what they have learned about the effect that physical features (such as density and currents) have on marine organisms to the Gulf of Maine ocean system. They analyze satellite photos of sea surface temperature and chlorophyll (evidence of phytoplankton biomass), bathymetry and current data, then make claims about how the bathymetry and currents affect life in the Gulf of Maine. As a culminating assignment, students write a story to explain what happens in the Gulf of Maine during a year, backing up their ideas with evidence and describing the role of the physical features of the Gulf of Maine.  **Lesson 5: Introduction to Stellwagen Bank** (*Two 50-minute sessions*)  So far in this unit, students have been delving into the relationships between the physical features of the Gulf of Maine and the organisms that live there. In the next three lessons, students will use what they have learned to explore ocean ecosystems in more depth. This lesson focuses on the Stellwagen Bank National Marine Sanctuary located within the Gulf of Maine. Students will learn how this area became a National Marine Sanctuary and explore its unique physical and biological features, as well as some of the problems that it faces.  **Lesson 6: Stellwagen Bank Ecosystem** (*Three 50-minute sessions*)  Students research and create a visual representation of a Stellwagen Bank food web, explaining the connections between living and nonliving things, and how the physical environment affects the marine species that live there. Students synthesize their knowledge to predict what would happen if one or two components of the food web disappeared or decreased in numbers. Finally, based on what they have learned, students create a written argument, making a claim about the interconnection of living and nonliving things in the Stellwagen Bank ecosystem.  **Lesson 7: Comparing Ocean Ecosystems** *(Two 50-minute sessions)*  Students work in groups to research the ecosystems of other National Marine Sanctuaries in order to investigate the common features of all ocean systems. They also determine how the goals of a National Marine Sanctuary relate to the individual ecosystem found there. Their findings are presented in a poster or digital story and the lesson culminates with a science talk focusing on the ways that the goals of each sanctuary match the individual needs of the ecosystem.  **Lesson 8: Human Impacts on the Ocean – Bycatch** *(Six 50-minute sessions)*  Students learn about the types of fishing gear that are used to harvest seafood and their impact on marine species and the environment. They are introduced to the problems associated with bycatch (via a hands-on simulation and videos), then research innovative designs (bycatch reduction devices) that are being tested to reduce bycatch. Finally, students (working in groups) will design a bycatch reduction device (using the Engineering Design Process) to reduce bycatch of a specific species for one type of fishing gear. During this process, they will consider the physical features, habitat and behaviors of the target species and the bycatch species. The final product will be a drawing or model of the design, along with an explanation of the basis of the design (what criteria were considered), how it works, and how the prototype would be tested. A poster and presentation (or digital story) will be created to convince a group of fishermen (the class) to install/implement their device.  **Lesson 9: Human Impacts on the Ocean – Overfishing** *(Five 50-minute sessions)*  Students participate in a hands-on activity that simulates overfishing and illustrates the effects of overfishing fish populations. After brainstorming ways that overfishing may be reduced/prevented, students research marine species that are overfished in New England. Next, students explore the question: “How do we know how many fish there are in the sea?” via a hands-on activity focusing on fish tagging and using statistics to estimate simulated fish populations.. This leads to an in-depth study of a real-world dilemma currently facing New England: overfishing of cod. Students learn about the history of cod fishing in New England (including recent actions that were taken based on inaccurate sampling data) and research the ecology of cod. Students then participate in a simulated debate about what should be done to bring the cod populations back to sustainable levels. In groups, students are assigned the roles of different stakeholders and research and build an argument based on their unique point of view.  **Lesson 10: Sustainable Seafood – Vote With Your Fork!** *(Six 50-minute sessions)*  The focus of this lesson is on steps that the public can take to help increase the sustainability of fish populations. Initially, students create a concept map showing what they know about the seafood they eat. They are then introduced to the concepts of “sustainability” and “sustainable seafood” by researching information on NOAA’s FishWatch website and watching online videos. After a class discussion, each student researches an overfished species from New England, creates a fact sheet, and presents the information to the class. Next, students work in groups to design a research project to gather information on the types of seafood that are sold in their community and how they are caught. The data will be represented in charts and graphs for presentation to the class along with the group’s interpretation of what the data implies. Following a science talk comparing the data, students write letters to area businesses that sell seafood presenting what they have learned and suggested actions that the businesses might take to help promote sustainability.  **CEPA: Spreading the Word About the Gulf of Maine** *(Two to three 50-minute sessions)*  As a culminating assessment, students work in groups to create a digital story, presentation, or other mode of communication outlining what they have learned about Ocean Systems in the Gulf of Maine designed to share with middle school students. The main goals of the project are to: 1) synthesize what they have learned in a clear and concise fashion, 2) communicate how important it is to take steps to save our valuable ocean system resources, and 3) empower the audience (middle school students) to take action in their community. | | |
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# Lesson 1: The Gulf of Maine-New England’s Ocean System

**Brief Overview of Lesson:** In this lesson, students are introduced to the Gulf of Maine, New England’s ocean system: its geography, geology, and marine life. After completing a pre-assessment, students read about the components of the Gulf of Maine system, create concept maps to describe what they learned, and participate in a class discussion.

**Prior Knowledge Required:** Concept mapping skills, familiarity with the concept of systems, basic understanding of ecosystems (producers, consumers, decomposers)

**Estimated Time:** Two 50-minute classes

**Standard(s)/Unit Goal(s) to be Addressed in This Lesson:**

* **HS-LS2-2** Use mathematical representations to support explanations that biotic and abiotic factors affect biodiversity, including genetic diversity within a population and species diversity within an ecosystem. Clarification Statements: Examples of biotic factors could include relationships among individuals (feeding relationships, symbiosis, competition) and disease. Examples of abiotic factors could include climate and weather conditions, natural disasters, and availability of resources. Examples of mathematical representations include finding the average, determining trends, and using graphical comparisons of multiple sets of data.

**Big Idea:**

* The Gulf of Maine is an ocean system made up of physical, geological, and biological components that interact with each other.

**Essential Question(s) Addressed in This Lesson:**

* What are the components of the Gulf of Maine ocean system and how do they interact with each other?

**Objectives:**

**Students will be able to…**

* Create a concept map outlining the biotic and abiotic components of the Gulf of Maine Ocean System and how they might be connected.

**Targeted Academic Language:** bank, bedrock, concept map, consumer, continental shelf, ecosystem, environment, geology, glacier, Gulf of Maine, ocean system, organism, phytoplankton, producer, system

**Anticipated Student Preconceptions/Misconceptions:**

* The ocean is not a system of parts that depend on each other.

**Instructional Materials/Resources/Tools:**

* Chart paper, markers, laptops (if using an online concept mapping tool)
* The Gulf of Maine map
* The Gulf of Maine reading
* Science notebooks

**Instructional Tips for Teacher:**

* Use a gallery walk to have students view and comment on each other’s concept maps. Description of the gallery walk strategy: http://www.schools.ccps.k12.va.us/sites/tp/hassell/Strategies/Gallery%20Walk.pdf
* If students are not familiar with making concept maps, the teacher may need to review and/or model how to make a concept map with the class first.
* Concept map background and information: 1) Kathy Schrock’s Guide to Everything, “Concept Mapping in the Classroom,” <http://www.schrockguide.net/concept-mapping.html> and 2) Gliffy ([www.gliffy.com](http://www.gliffy.com))
* Students should have access to their concept maps throughout the entire unit so they can revise/add to them. (The concept maps will act as visible tracks of their learning and thinking during the unit.)

**Assessment**

* Formative**:** Do you think the ocean is a system? If so, what do you think some of the parts of the system might be? How might they interact? Explain your thinking. (This formative assessment is given at the beginning of the lesson to assess students’ background knowledge.)
* Summative: Concept maps (Concept maps are created after students read about the Gulf of Maine. They can be used to assess their understanding of what they read.)

**Lesson Details:**

**DAY 1 – Introduction to the Gulf of Maine (50 minutes)**

1. Explain that this unit focuses on the ocean system. Review the definition of “system” (a collection of interdependent parts enclosed within a defined boundary), providing some examples (such as human body systems, the solar system, etc.).
2. Ask students to write a written response to the following prompt in their science notebook: “Do you think the ocean is a system? If so, what do you think some of the parts of the system might be? How might they interact? Explain your thinking.”
3. Students turn and talk with a partner about their ideas, then share out ideas with the whole class.
4. Explain that in this unit they will be studying the ocean system, specifically focusing on New England’s ocean system: The Gulf of Maine. Project the Gulf of Maine map and explain the major landmarks (such as Boston, Cape Cod, Portland, Maine) so that students understand what it shows.
5. Have students read The Gulf of Maine reading. Focus questions for the reading: What are the components (parts) of the Gulf of Maine Ocean System? How do those components interact? (Make sure these focus questions are visible for students to refer to as they read, e.g., on the board or Powerpoint.)

**DAY 2 – Concept Maps of the Gulf of Maine Ocean System (50 minutes)**

1. Ask students to create a concept map entitled The Gulf of Maine Ocean System (working in pairs). (The concept maps can be created on chart paper or online with a free tool such as Gliffy.) Focus questions for the concept maps: What are the components (parts) of the Gulf of Maine Ocean System? How do those components interact? Note: If students are not familiar with making concept maps, the teacher may need to review and/or model how to make a concept map with the class first.
2. Post the concept maps around the room and do a gallery walk. Alternatively, if class blogs were used, ask students to comment on the blogs of at least two other groups.
3. Share ideas in a whole class discussion. Explain that students will have the chance to modify and add to their concept maps as they learn more about the Gulf of Maine in this unit.
4. Explain that in the next class, they will be exploring the effect of temperature and salinity (the amount of salt in sea water) on the ocean system.
5. For **homework**, answer the following questions (written or in a blog post):
   * What do you think causes different sea water temperatures in the ocean? (*Different parts of Earth get different amounts of sunlight. Also, deeper water receives less sunlight than surface water, and thus will be colder.*)
   * Do you think that all ocean water has the same salinity? Explain your thinking.

# Lesson 2: Ocean Layers

**Brief Overview of Lesson:** Students conduct investigations to explore how temperature and salinity affect the density of water and create layers in the ocean. These layers, in part, are a factor in the formation of ocean currents (which will be discussed in Lesson 3). Temperature and salinity also can affect the geographic distribution of marine organisms. Students explore how nutrients relate to productivity and how primary producers provide energy for ecosystems.

**Prior Knowledge Required:** The ocean is heated by the sun in the upper layers and that heating of the ocean is uneven on a global scale, the structure of water molecules, the difference between hydrogen bonds and covalent bonds, the concept of density and buoyancy, density is mass per unit volume, the buoyant force on an object in a fluid is an upward force equal to the weight of the fluid the object has displaced, and the basic properties of water, such as water as a universal solvent and its high heat capacity. In addition, students should be able to calculate the density of substances from measurements of mass and volume, and predict whether an object will float or sink. Students should also be familiar with the concept of models.

**Estimated Time:** Three 50-minute classes

**Standard(s)/Unit Goal(s) to be Addressed in This Lesson:**

* **HS-LS2-2** Use mathematical representations to support explanations that biotic and abiotic factors affect biodiversity, including genetic diversity within a population and species diversity within an ecosystem. Clarification Statements: Examples of biotic factors could include relationships among individuals (feeding relationships, symbiosis, competition) and disease. Examples of abiotic factors could include climate and weather conditions, natural disasters, and availability of resources. Examples of mathematical representations include finding the average, determining trends, and using graphical comparisons of multiple sets of data.

**Big Ideas:**

* Water with higher density sinks to the bottom while water with lower density sits on the top.
* Temperature and salinity affect the density of water.
* Cold ocean water is more dense than warmer water. Therefore, it sinks, creating layers within the ocean.
* Water with higher salinity is denser than water with lower salinity. Therefore, it sinks, creating layers within the ocean.
* Phytoplankton are primary producers in the ocean food web. They require sunlight, carbon dioxide, water and nutrients for photosynthesis.
* Understanding the layers of the ocean helps explain the ocean currents and consequently the distribution of marine organisms.
* Productivity in the ocean system may be seasonal depending on the amount of sunlight available to heat ocean water (latitude).

**Essential Question(s) Addressed in This Lesson:**

* What are the components of the ocean system and how do they interact with each other?
  + How do temperature and salinity affect the density of ocean water? What effect does this have on marine organisms?
  + What is the role of phytoplankton in the ocean ecosystem? What do they need to survive?
  + How does primary production by phytoplankton vary seasonally by latitude?

**Objectives:**

**Students will be able to…**

* Use models to gather evidence to show how abiotic factors (ocean water temperature and salinity) affect density and create layers of water in the ocean.
* Explain how differing temperature and salinity throughout the ocean results in layering.
* Explain how abiotic factors influence phytoplankton populations, and therefore all ocean food webs.

**Targeted Academic Language:** density, dissolve, energy, latitude, model, nutrients, organism, photosynthesis, phytoplankton, primary producers, primary production, salinity, sunlight, temperature, thermocline, variable

**Anticipated Student Preconceptions/Misconceptions:**

* Phytoplankton are too small to be important
* Oceans have the same salinity everywhere
* Salinity changes cause temperature changes (and vice versa)
* Upwelling occurs as deeper water layers warm and rise
* Upwelling occurs as deeper water layers lose their salinity and rise

**Instructional Materials/Resources/Tools:**

* Investigation Materials: Triple beam balances or other accurate scales, one pound table salt, two colors of food coloring (red and blue), a clear plastic shoebox-sized container for each pair of students, two 500-ml beakers for each pair of students, ice and a source of hot water (Video camera/camera optional.)
* Visual Aids for the Teacher: Ocean Layers Diagram-Blank, Structured Layering of the Ocean Diagram, Phytoplankton Photo, and Seasonal Productivity in Surface Waters Diagram, projector and computer for projecting images
* Optional Interactive Read Aloud: *Ocean Sunlight: How Tiny Plants Feed the Seas* by Molly Bang and Penny Chisholm, The Blue Sky Press, 2012 and the Ocean Sunlight Interactive Read Aloud Plan

**Instructional Tips for Teacher:**

* After completing their investigations, provide time for students to share their results with the whole group. Chart out class results. Facilitate a science talk to give students a chance to explore their thinking about the essential questions and questions that they still have.
* If students are not familiar with models, the teacher will need to provide background.
* For information on using interactive read aloud in the high school science classroom, see: <http://teachersnetwork.org/ntol/howto/science/readscien.htm>
* If possible, it might be helpful to videotape or take photos, during the investigations to document what happens.

**Assessment:**

* Formative**:** Homework assigned at the end of Lesson 1:
  + What do you think causes different sea water temperatures in the ocean? (*Different parts of Earth get different amounts of sunlight. Also, deeper water receives less sunlight than surface water, and thus will be colder.*)
* Do you think that all ocean water has the same salinity? Explain your thinking.
* Summative: Homework (See end of Day 1, Day 2 and Day 3 for details)

**Lesson Details:**

**DAY 1 – What Happens When Warm and Cold Water Mix in the Ocean?**

1. Briefly share ideas from the homework/blog post. Tell the class that today, they are going to make models to investigate the question of what happens when warm and cold water mix in the ocean, and what happens when salty water (high salinity) and less salty water (lower salinity) mix in the ocean. Then, they’ll explore how the results might affect the geographic distribution of marine organisms. [Note: If students are not familiar with models, the teacher will need to provide background.]
2. Organize students into groups of two to three. Distribute materials for the experiment to each group. Explain that they are going to create models of the ocean system.
3. Have each group create 2 liters of “sea water” in their plastic container by dissolving 70 grams (about 7 tablespoons) of salt in 2 liters of room temperature water (this roughly approximates the salinity of seawater at 3.5%).

Temperature Test

1. Fill one 500 ml beaker with water and add 1.75 tablespoons of salt (3.5%). Put it in an ice bath for 10-15 minutes. (Cold water)
2. While the cold water beakers are chilling, ask students to make predictions in their science notebooks: “What do you think will happen when you mix cold sea water and hot sea water? Why do you think that?”
3. When the cold water beaker is chilled, fill the other 500 ml beaker with hot tap water and add 1.75 tablespoons of salt (3.5%) (Hot water)
4. Add a drop of red food coloring to the hot water beaker and a drop of blue food coloring to the cold water beaker.
5. After they take the temperature of each beaker (and record the temperatures), have students gently pour the contents of each of their beakers into the opposite ends of their plastic container. They will make observations and draw/record what happens in their science notebooks, labeling the hot and cold water. It might be helpful to videotape or take photos if possible to document what happens. *Note: If the beakers are poured into the container too quickly, the experiment will not work.*
6. Have students dump out and rinse their containers when they are done with the investigation.
7. Ask students to share their observations and discuss as a class what was happening in the containers after the beakers were added. Where in the ocean might there be colder water and warmer water?
8. Homework: When you mix warmer and colder water, what happens? Why? Include evidence from your investigations to support your claim.

**DAY 2 – What Happens When Waters With Different Salt Content (Salinity) Mix in the Ocean?**

1. Briefly share ideas from the homework and review what was done in the Day 1 temperature investigation. Explain that today they are going to investigate the effect of salinity on mixing, using the same type of models.

Salinity Test

1. Ask students to dump out and rinse their containers.
2. Have all students make a liter of sea water (3.5%--35 grams NaCl per liter of water) and pour it into their plastic container.
3. Explain that half of the groups are going to make sea water that is ¼ as salt as “normal” sea water by mixing 875 grams of salt per liter. (This solution will be colored blue.)
4. The other half of the groups will make sea water that is 4 times as salty by dissolving 120 grams of salt in a liter of water. (This solution will be colored red.)
5. Ask students to predict in their science notebooks: “What do you think will happen when you mix very salty sea water (high salinity) and water that is less salty (low salinity)? Why do you think that?”
6. Ask students to share half of their solutions with a group that has made the other solution. Make sure the solutions are clearly labeled.
7. Direct students to carefully pour the contents of the beakers of high and low salinity solutions into opposite ends of the container and observe what happens. They should draw/record their observations in their science notebooks.
8. Ask students to share their observations and discuss as a class what was happening in the containers after the beakers were added. Where in the ocean might water with higher salinity than normal sea water exist? What about water with lower salinity than normal sea water?
9. Homework:

* When you mix warmer and colder water, what happens? Why? Include evidence from your investigations to support your claim.
* When you mix water that has a high salinity with water that has a lower salinity, what happens? Why? Include evidence from your investigations to support your claim.

**DAY 3 – Ocean Layers**

1. Review the investigation findings from the previous day and the homework questions.
2. Explain to students that as you go deeper in the ocean, variables such as salinity, pressure, density, and temperature change. Layering occurs when waters of different characteristics meet. Tell students that understanding these layers and how they mix helps scientists determine how different kinds of life are distributed in the ocean.
3. Give students the Ocean Layers Diagram-Blank. Ask students “how do you think temperature and salinity changes as water gets deeper?” (*Temperatures will go down as the depth* *increases. Salinity will increase with depth.*) Ask students to reflect in their science notebooks, then turn and talk.
4. Project the Structured Layering of the Ocean diagram and explain that ocean waters can be divided into three layers, or zones, based on their densities:

* **Surface layer:** The mixed layer that is well stirred by the wind and other forces. This layer tends to be warmest due to heating from the sun. Warmer water at the surface is less dense than cooler water. Saltier water is more dense than fresher water, so it sinks.
* **Intermediate, or transition, layer (thermocline):** Significant changes in density occur at this layer, which acts as a barrier between the warm surface layer and the cold deep ocean (deep layer). In this layer, temperature changes rapidly with depth. (This layer often coincides with the halocline, the region where salinity changes sharply with depth.)
* **Deep layer:** Water in this layer is cold and dense. Temperature and salinity tend to remain relatively constant below the thermocline.

Ask students how the diagram relates to what they found in their experiments. (*As seen in the experiment, cold, dense water is found in the deep layers, and warm, less dense water is found in shallow layers.*)

1. Referring still to the Structured Layering of the Ocean diagram, tell students that the average temperature of the ocean’s surface water is approximately 63° F (16° C). Point out the thermocline, the layer of water where temperature changes rapidly in relation to depth; explain that the temperature fluctuation corresponds with a density change. (*Note: Tell students that the density of ocean water* *continuously increases with decreasing temperature until the water freezes.*) Tell students that more than 90% of the total volume of ocean water is below the thermocline. Tell students that the layer of water beneath the thermocline does not mix well with the warm layers above it because of its density, just like students observed in their experiment. Point out the portion of the graph of density versus depth. Ask students, “How does density change with depth?” (*The deeper the water, the more dense it is. Denser water sinks.*)
2. Explain to students that understanding the layers of the ocean helps explain the distribution of marine organisms that live there. Tell students to brainstorm with a partner and answer the question: “What variables do you think are important to life in the ocean, and what resources do plants or animals need to survive?” (*Sunlight, nutrients, food sources, temperature, and salinity*)
3. Project the Phytoplankton photo, and explain that these organisms, which drift in the upper layers of the ocean, form the base of the marine food chain and determine the other species that live in a given location. Tell them that these organisms are microscopic plants that are capable of producing food energy from photosynthesis. Explain that phytoplankton are primary producers—they convert solar or chemical energy to organic energy that can be used by organisms in an ecosystem.
4. Tell students that phytoplankton need sunlight, carbon dioxide, water and nutrients—nitrogen compounds and phosphates—in order to conduct photosynthesis. Explain that nitrogen compounds and phosphates come from the decomposition of dead plants. Ask students:

* Where do you think that sunlight, carbon dioxide and nutrients would be found in ocean waters? (*Sunlight is strongest near the surface of the water; nutrients usually sink to the bottom of the ocean.*)
* How would the thermocline affect nutrient distribution? (*The layer beneath the thermocline would be nutrient-rich. A strong thermocline would trap nutrients in deep waters.*)
* If nutrients get trapped beneath a thermocline, how would this affect phytoplankton? (*Phytoplankton cannot grow and survive in areas without nutrients.*)
* How would this affect other organisms? (*Other organisms that eat phytoplankton or feed on organisms that eat phytoplankton would not be found in areas where nutrients are trapped beneath the thermocline.*)

Optional Interactive Read Aloud: *Ocean Sunlight: How Tiny Plants Feed the Seas* by Molly Bang and Penny Chisholm. See <http://the-curious-scientist.weebly.com/curriculum.html> for an example of an interactive read aloud plan for this book.

1. Explain to students that thermoclines are different throughout oceans. Ask students to think about the globe: “Where do you think thermoclines would be strongest?” (*Tropical latitudes, because these get the most consistent amount of light to* *heat the waters.*)
2. Project the graph on the bottom of the Structured Layering of the Ocean diagram and point out how thermoclines differ depending on whether a region is polar, temperate, or tropical.
3. Project the Seasonal Productivity in Surface Waters diagram. Point to the lines for “Tropical Productivity,” “Temperate Productivity,” and “Polar Productivity.” Ask students to identify the approximate latitude that is identified on the graph for each region. (*Tropical appears as about 25° on the chart but runs from 23.5° South to 23.5° North. Temperate* *appears as about 50° on the chart but runs from 23.5° North to 66.6° North, and 23.5° South to 66.6° South. Polar appears as* *about 72° on the chart but runs from 66.6° North to 90° North, and 66.6° South to 90° South.*)
4. Using the Seasonal Productivity in Surface Waters diagram, point out and discuss the following patterns:

* **Low latitudes (tropical regions):** A consistent amount of light falls throughout the year in these latitudes, resulting in a constant warm temperature and creating a permanent thermocline. The concentration of nutrients is low all year long.
* **Middle latitudes (temperate regions):** Beginning in the spring, these latitudes receive enough sunlight to support phytoplankton blooms, but the phytoplankton can rapidly use up all available nutrients. These middle latitudes experience a seasonal thermocline due to the increased solar radiation entering the waters. The thermocline blocks nutrients from the deep, colder, denser waters below from moving upwards, and the surface waters can quickly become nutrient poor. Primary production drops significantly in the surface waters toward the end of the summer. As solar radiation decreases and winds increase in the fall, the thermocline dissipates, and nutrients once again become available for the phytoplankton.
* **High latitudes (polar regions):** Since only seasonal heating takes place in these latitudes, there are not permanent thermoclines. In summer, the upper layers generally mix with deeper, nutrient-rich water, resulting in nutrient-rich surface waters. In the summer season, while there is more sunlight due to longer days, huge phytoplankton blooms form in the polar surface waters.

1. Tell students that the black lines on the Seasonal Productivity in Surface Watersdiagram indicate primary productivity, and thus serve as an indicator of the amounts of nutrients available to other marine organisms. Discuss the following:

* At tropical latitudes, what keeps productivity low? (*Nutrients are trapped by a permanent thermocline. This occurs because the region receives consistent sunlight to create constant warm temperatures.*)
* At polar latitudes, what happens to productivity in the summer? Why? (*Productivity increases because the amount of sunlight increases. Nutrients are mixed throughout the layers of water, allowing phytoplankton to bloom.*)
* At temperate latitudes, what happens to productivity in the beginning of spring? Why? (*Productivity increases because sunlight increases. A thermocline has not developed to trap nutrients yet.*)
* At temperate latitudes, what happens to productivity in the fall? (*Productivity increases. As light decreases and winds increase, the thermocline dissipates, allowing nutrients to become accessible to phytoplankton.*)

1. Homework: How could the properties of ocean water (such as temperature and salinity) affect the geographic distribution of coastal and marine organisms? ***(****Note: Students should reflect on the relationship between the organisms and their physical environment. The demonstration showed students how a thermocline can act as a physical barrier and this barrier can in turn prevent nutrients from reaching the surface layer where they are needed for photosynthesis. Blocking of nutrients causes a ripple effect on the distribution of all organisms in an ecosystem, since organisms that form the second tier of a food chain can only grow in the presence of primary producers who depend on essential nutrients.****)***

**Teacher Background**:

Cold water is denser than warm water and will sink below the warmer water. Water that is more saline is also denser than water with lower salinity and will sink below water of lower salinity. Water temperature has more of an effect on water movement than salinity.

Living things possess specific adaptations to natural environments that result in predictable species distribution patterns. In the ocean, the chemical and physical environment, along with the physiological adaptations of organisms, influence geographic distribution of animals and plants. Latitude also helps predict the geographic distribution of marine organisms. Different marine organisms live in polar (high latitude), temperate (midlatitude), and tropical (low latitude) climates. Variations in distribution also result from differing temperatures, salinity, density, and nutrient availability across latitudes. At low latitudes most of the heat energy that enters the ocean comes from the Sun. A consistent amount of light falls in these areas throughout the year because the Sun hits these latitudes at a more direct angle than in other areas. Thus, ocean water to a depth of approximately 200 feet at low latitudes remains at a constant warm temperature throughout the year, creating a permanent thermocline.

Primary producers (phytoplankton) use the nutrients in these surface waters to facilitate photosynthesis and reproduction. These organisms form the base of the entire marine food chain. Due to only seasonal heating of ocean waters from the Sun, no permanent thermocline exists at higher latitudes (polar regions). In summer, the upper layers generally mix with deeper waters rich with nitrogen and phosphates, resulting in nutrient-rich surface waters. In the summer season when there is more sunlight due to longer days, huge phytoplankton blooms form in the polar surface waters. These blooms form the base of the food chain. Beginning in the spring, midlatitudes (temperate regions) receive enough sunlight to support phytoplankton blooms, but the photosynthetic phytoplankton can rapidly use up all available nutrients during photosynthesis and reproduction. These midlatitudes experience a seasonal thermocline due to the increased solar radiation entering the waters and less physical mixing due to lighter winds (which results in smaller waves). The thermocline blocks nutrients from the deep, colder, denser waters below from moving upwards, and the surface waters can quickly become nutrient poor. Primary production drops significantly in the surface waters toward the end of the summer. As solar radiation decreases and winds increase in the fall, the thermocline dissipates, and nutrients once again become available for the phytoplankton at the midlatitudes.

**Sources for This Lesson:**

* NOAA, Lesson 6: Ocean Layers I, <http://www.st.nmfs.noaa.gov/Assets/Nemo/documents/lessons/Lesson_6/Lesson_6-Teacher's_Guide.pdf>.
* The California Education and Environment Initiative, Unit E.5.d, Ocean Currents and Natural Systems, pp. 52-68.
* The Curious Scientist website, <http://the-curious-scientist.weebly.com/curriculum.html>.

**Additional Resource:** Cerullo, Mary M. *Sea Soup: Phytoplankton.* Gardiner, Maine: Tilbury House, Publishers, 1999.

# Lesson 3: How Do Ocean Currents Influence Marine Organisms?

**Brief Overview of Lesson:** Students learn how the Earth’s ocean currents (horizontal and vertical) are affected by energy from the sun heating the Earth, the planet’s rotation, and wind. They analyze maps and apply what they have learned in previous lessons via class discussions. Ultimately, students extend their thinking to grapple with the question of how ocean currents influence the geographic distribution of marine organisms.

**Prior Knowledge Required:** The circular motions of ocean currents and air pressure centers, Earth’s rotation and its effect on ocean currents, uneven heating of the ocean and Earth’s surface, ecosystem, primary producers

**Estimated Time:** One 50-minute class

**Standard(s)/Unit Goal(s) to be Addressed in This Lesson:**

* **HS-LS2-2** Use mathematical representations to support explanations that biotic and abiotic factors affect biodiversity, including genetic diversity within a population and species diversity within an ecosystem. [Clarification Statements: Examples of biotic factors could include relationships among individuals (feeding relationships, symbiosis, competition) and disease. Examples of abiotic factors could include climate and weather conditions, natural disasters, and availability of resources. Examples of mathematical representations include finding the average, determining trends, and using graphical comparisons of multiple sets of data.]

**Big Ideas:**

* Ocean currents influence the diversity and distribution of marine organisms.
* Patterns of global horizontal ocean currents are affected by energy from the Sun heating Earth, the planet’s rotation and wind.
* Vertical currents (e.g., upwellings) bring cold, nutrient-rich waters from the ocean’s depths to the surface. These nutrients are used by phytoplankton (the foundation of the ocean food web).

**Essential Question(s) Addressed in This Lesson:**

* What are the components of the ocean system and how do they interact with each other?
  + How are ocean currents formed?
  + What effect do ocean currents have on the distribution of marine organisms?

**Objective:**

**Students will be able to…**

* Use evidence to explain how abiotic factors (such as the layered structure of the ocean, and horizontal and vertical currents) influence the biodiversity (geographic distribution) of marine organisms.

**Targeted Academic Language:** consumers,equator, equatorial regions,gyre, marine debris, ocean current, polar regions, upwelling, zooplankton

**Anticipated Student Preconceptions/Misconceptions:**

* Ocean currents are caused by tides (and no other factors).
* Earth’s oceans are separate and not connected.
* Upwelling occurs as deeper water layers warm and rise.
* Upwelling occurs as deeper water layers lose their salinity and rise.

**Instructional Materials/Resources/Tools:**

* Major Ocean Currents map and Uneven Heating of Earth diagram
* Projector/computer/internet access for video
* Science notebooks

**Instructional Tips for Teacher:**

* It may be helpful for each pair of students to have a copy of the Major Ocean Currents map to look at. Copies can be printed out and laminated to extend their lifespan.

**Assessment**

* Formative**:** What do you think are the causes of ocean currents? Do you think that they have any effect on marine organisms? Explain your thinking.
* Summative: Homework: 1) How do ocean currents affect the distribution of marine organisms? 2) If you were an oceanographer looking for areas of upwelling, what kind of evidence would you gather (i.e., what would you test ocean water for)? Explain your thinking.

**Lesson Details:**

1. Explain that the class will now be learning about ocean currents. Ask students to write responses to the following in their science notebooks: What do you think are the causes of ocean currents? Do you think that they have any effect on marine organisms? Explain your thinking. Ask students to turn and talk to a classmate, then share with the whole class.
2. Project the Major Ocean Currentsmap. Ask students to make observations about the map, especially the patterns they notice. Ask them to turn and talk, then share ideas with the whole class. Have students help locate some of the major ocean currents, such as the North Atlantic Drift, Gulf Stream, and California Current, Humboldt Current, and the Equatorial Countercurrents.
3. Project the Uneven Heating of Earth diagram. Point out that the sun heats the ocean primarily at low latitudes and then those heated waters move away from the equator toward Earth’s polar regions. Trace the flow of the water from the equatorial regions toward the polar regions. Explain that as the ocean water moves away from the equator (north or south), it cools and becomes denser. Ask the students, “What happens to the water as it becomes colder and denser?” (*Colder and* *denser water will sink below warmer water*.) Point out this flow and the sinking process on the diagram.

Use the following questions to review students’ understanding of the investigations they conducted in Lesson 2:

* As cold water moves into a region, what happens to it? (*It sinks beneath the warmer water.*)
* As warm water moves into a region, what happens to it? (*It floats above the colder water.*)

Remind students that the movement of warm and cool waters produces layers of ocean water that vary in temperature, just like the layers they saw in their experiments. Watch the Global Ocean Circulation video (WGBH, 4:48 minutes), <http://www.pbslearningmedia.org/resource/nves.sci.earth.oceancirc/global-ocean-circulation>.

1. Point to the major gyres on the map, the North Pacific Drift and North Atlantic Drift. Explain that a gyre is the circular or horizontal movement of water. Explain to students that wind, as a result of the uneven heating of Earth, has a great influence on the horizontal currents of ocean-surface waters. Using the Major Ocean Currents map,point out that ocean water moves in a clockwise direction in the Northern Hemisphere and a counterclockwise direction in the Southern Hemisphere.
2. Tell students that one visible effect of these ocean gyres is the accumulation of large quantities of marine debris. The circular motion of the gyres brings together plastics and other waste materials from around the world. One of the most notable examples is called the “Great Pacific Garbage Patch.” The area affected by this garbage patch is estimated to cover up to 8% of the surface of the Pacific Ocean, and it may contain as much as 100 million tons of debris. This mass of plastic blocks sunlight, which in turn can affect water temperature, as well as the food and oxygen available to marine organisms. Students can explore websites about marine debris to learn more, including: <http://5gyres.org>, and <http://marinedebris.noaa.gov/marinedebris101/mdinfo.html>. Optional video: One Beach by Barefoot Wine, <http://www.youtube.com/watch?v=yP-GXSryNKs>. (See extension lesson, Plastics in the Water Column, noted below.)
3. Explain that the focus so far has been on horizontal currents, now they will learn about vertical currents. Introduce students to “upwellings,” an example of vertical coastal currents. Winds blowing across the ocean surface often push water away from an area. When this occurs, water rises up from beneath the surface to replace the diverging surface water. This process is known as “upwelling.” Explain that, near the coast, these vertical currents bring cold, nutrient-rich waters from the ocean’s lower layers up to the surface, where they support an extensive and complex food web that includes secondary and tertiary consumers, including top predators. The nutrient-filled waters allow phytoplankton to flourish at the surface and provide a constant food source for other marine organisms, such as zooplankton and a multitude of fish and marine mammals.

Ask students, “How do you think these upwellings and the associated high levels of nutrients might affect the distribution of marine and coastal organisms?” (*There will be more organisms in the areas of these upwellings because the* *nutrients will increase the growth of phytoplankton and zooplankton, which in turn will support the growth of fish and many* *other organisms.*)

1. Homework. Ask students to write responses to the following:

* How do ocean currents affect the distribution of marine organisms?
* If you were an oceanographer looking for areas of upwelling, what kind of evidence would you gather (i.e., what would you test ocean water for)? Explain your thinking.

The next day, have students turn and talk to a partner about the homework questions, then share out with the whole group.

**Extension:** ‘Plastics in the Water Column,” Monterey Bay Aquarium, <https://www.montereybayaquarium.org/-/m/pdf/education/curriculum/aquarium-6-8-plastics-in-thewater-column.pdf>

**Source for This Lesson:**

* The California Education and Environment Initiative, Unit E.5.d, Ocean Currents and Natural Systems, pp. 52-68.

**Optional Resources:**

* 5 Gyres website, <http://5gyres.org>,
* NOAA Marine Debris website, <http://marinedebris.noaa.gov>
* Optional video: One Beach by Barefoot Wine, <http://www.youtube.com/watch?v=yP-GXSryNKs>

**Teacher Background**

Ocean waters are constantly moving, usually in regular and predictable patterns. Two variables influence the patterns of global ocean currents: energy from the Sun heating Earth, and the planet’s rotation. Wind, a result of the uneven heating of Earth, exerts the greatest influence on horizontal currents of the ocean’s surface waters. As a result of wind pressure, macroscale horizontal currents, or gyres, travel around the globe, interrupted only by land masses. Winds push water heated at the surface at low latitudes in a circular motion toward the poles. As the supersaline water moves away from tropical latitudes, it cools and the denser water sinks beneath the temperate, less saline water to form stratified layers in the fluid ocean. In the Northern Hemisphere, the horizontal currents of wind and ocean water travel clockwise; in the Southern Hemisphere they move counterclockwise. All of these currents influence the diversity and distribution of organisms in the ocean. Smaller, more local currents also influence the distribution of marine organisms. Local vertical currents, such as those formed by upwelling or by land masses (for example, a peninsula), determine the unique physical and chemical properties—and thus biological properties—of specific coastal areas. One well-known example of the effects of local currents on an ecosystem occurs as a result of upwelling in the Gulf of Maine. Vertical currents off the coast bring nutrient-rich waters from the ocean’s lower layers up to the surface where they support a massive, complex food web that includes secondary and tertiary consumers (top predators). The nutrient-filled waters allow phytoplankton to flourish at the surface and provide a constant food source for other marine organisms, such as zooplankton (animal plankton) and a multitude of fish and marine mammals. The abundant marine life in the area has supported a huge fishing industry for hundreds of years.

**Source**: Adapted from California Education and the Environment Initiative, Unit E.5.d, Ocean Currents and Natural Systems, pp. 70-76.

# Lesson 4: Using Satellite Data to Tell the Story of the Gulf of Maine

**Brief Overview of Lesson:** Students extend what they have learned about the effect that physical features (such as water density and currents) have on marine organisms to the Gulf of Maine Ocean System. They analyze satellite photos of sea surface temperature and chlorophyll (evidence of phytoplankton biomass), bathymetry and current data, then make claims about how the bathymetry and currents affect life in the Gulf of Maine. In a culminating assignment, students write a story to explain what happens in the Gulf of Maine during a year, backing up their ideas with evidence and describing the role of the physical features of the Gulf of Maine.

**Prior Knowledge Required:** Basic map skills, an understanding of the effects that physical features (such as ocean water density and currents) have on marine species, understanding of primary productivity, and previous practice with constructing explanations (making claims based on evidence connected by reasoning).

**Estimated Time:** Four 50-minute classes

**Standard(s)/Unit Goal(s) to be Addressed in This Lesson:**

* **HS-LS2-2** Use mathematical representations to support explanations that biotic and abiotic factors affect biodiversity, including genetic diversity within a population and species diversity within an ecosystem. Clarification Statements: Examples of biotic factors could include relationships among individuals (feeding relationships, symbiosis, competition) and disease. Examples of abiotic factors could include climate and weather conditions, natural disasters, and availability of resources. Examples of mathematical representations include finding the average, determining trends, and using graphical comparisons of multiple sets of data.
* **W.9-10.1** Write arguments (e.g., essays, letters to the editor, advocacy speeches) to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.
* **W.11-12.1** Write arguments (e.g., essays, letters to the editor, advocacy speeches) to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.

**Big Ideas:**

* Oceanographers use satellite data to gather useful information on large areas of the ocean
* The physical features of the ocean and other abiotic factors affect where marine species can survive and thrive, the time of year they reproduce and grow, and how their eggs and food are transported
* Productivity in the ocean system may be seasonal depending on the amount of sunlight available to heat ocean water (latitude).

**Essential Question(s) Addressed in This Lesson:**

* What are the components of the ocean system and how do they interact with each other?
  + How do the physical features of the Gulf of Maine (such as currents, water temperature, geology) and other abiotic factors influence where certain marine species can survive, what time of year they will reproduce and how their eggs and food are transported?

**Objectives:**

**Students will be able to…**

* Analyze and use data to support explanations that biotic and abiotic factors affect biodiversity.
* Read and interpret satellite images of sea surface temperature and chlorophyll (a measure of phytoplankton biomass).
* Make claims about how the physical features of the ocean affect living things based on satellite image evidence.

**Language Objective:**

**Students will be able to…**

* Write claims based on evidence (connected by reasoning) and communicate them through argument writing.

**Targeted Academic Language:** bathymetry, biomass, bloom, chlorophyll, phytoplankton, oceanographer, satellite, sea surface temperature

**Anticipated Student Preconceptions/Misconceptions:**

* The bottom of the ocean is flat.
* The ocean is basically a big bowl, deepest in the middle.
* Nothing lives in the middle of the ocean.

**Instructional Materials/Resources/Tools:**

* Maps and images: Gulf of Maine map, Gulf of Maine Sea Surface Temperature (SST) Satellite Images (2012 monthly composites) from the University of Maine. (One set per 2-4 students), Gulf of Maine Chlorophyll Satellite Images (2012 monthly composites) from the University of Maine. (One set per 2-4 students), Gulf of Maine Bathymetry map (one per 2-4 students), Gulf of Maine Currents map (one per 2-4 students)
* Readings: “Seasons in the Sea” by Dr. Ann Michelle Morrison (one copy per student)
* Rubrics: Argument Writing in Science Rubric (Grades 9-10), Argument Writing in Science Rubric (Grades 11-12)
* Projector/computer
* Science notebooks

**Instructional Tips for Teacher:**

* Composite monthly satellite images for various years are available from the University of Maine Satellite Oceanography Data Lab website, <http://www.seasurface.umaine.edu/sat_ims.htm>. As an extension, students could look at monthly composites from different years to observe yearly patterns and/or changes over time. Why might these changes be occurring?
* For information on constructing explanations:” Designing Science Inquiry: Claim + Evidence + Reasoning = Explanation,” Edutopia, <http://www.edutopia.org/blog/science-inquiry-claim-evidence-reasoning-eric-brunsell>
* It is recommended that you laminate sets of the colored satellite photos. In some cases, it may be preferable to post the photos in chronological order in a hallway or along a long wall in order for students to see them more easily.
* For information on facilitating science talks: Talk Science Primer, TERC (<http://inquiryproject.terc.edu/shared/pd/TalkScience_Primer.pdf>), Goals for Productive Discussions and Nine Talk Moves, TERC (<http://inquiryproject.terc.edu/assessment/Goals_and_Moves.cfm>),

**Assessment:**

* Formative**:** How do you think oceanographers gather data to study the physical features of ocean water and other things in the vast ocean? Explain your thinking.
* Written Assessment: Individually, ask students to write a paragraph or blog post that includes at least one claim about how the physical features of the Gulf of Maine influence where certain species can survive and thrive, what time of year they will reproduce and grow, or how their eggs and food get transported. Evidence must be provided from what they have learned. (Share the Argument Writing in Science Rubric with students)
* Project: Write a story to explain what happens to phytoplankton in the Gulf of Maine during a year. Back up your ideas with evidence. Be sure to describe the role of the physical features of the Gulf of Maine (bathymetry, currents, sea surface temperature) in your story. The story may be presented in written form (story, poster, comic strip), as a PowerPoint or digital story, or may be acted out.

**Lesson Details:**

**DAY 1 – Analyzing Sea Surface Temperature Satellite Images of the Gulf of Maine**

1. Ask students to individually write a response to the following question: How do you think oceanographers gather data to study the characteristics of ocean water in the vast ocean? Explain your thinking. Have students turn and talk to a partner about their ideas, then share with the whole class.
2. Explain that in the past, ocean research had to rely on data from individual sampling stations. Now, oceanographers use buoy data, satellite data and other methods to gather information about very large areas of the ocean.

Many types of satellite data are used to create color-coded images so that the information is easy to read. Two useful parameters that can be studied using satellite images are sea surface temperature (SST) and surface chlorophyll-a (Chl) levels. SST allows scientists to follow the movements and interactions of surface water masses, infer upwelling, and observe the effects of wind and storm events. Chl images show us the levels of phytoplankton in the upper meter of the ocean, including high concentrations during bloom events.

Explain that they are going to study some SST and Chl satellite images from the Gulf of Maine (project the Gulf of Maine map and point out the key geographic features). They will make observations about different sets of satellite images, and then make claims about how the physical features and geology of the Gulf of Maine influence where species can survive, what time of year they will reproduce and grow and how their eggs and food are transported.

1. Project one of the SST satellite images and ask students what they notice. Share ideas. Point out the important features of the image:

* The scale bar and units of measure (Explain what the scale bar means in relation to the colors in the image.)
* Key geographic features: Boston, Cape Cod, Georges Bank, Portland, Nova Scotia, Bay of Fundy
* Information in the legend
* Latitude and longitude marks around the edges of the image

1. Divide the class into groups of 2-4 students. Hand out a packet of sea surface temperature images (January through December 2007) to each group and ask them to arrange them in chronological order. They should make observations about what they notice and record them in their science notebooks, along with the questions they have. Focus question: How does sea surface temperature change over time in the Gulf of Maine?
2. Bring the class back together and ask each group to share what they noticed. Record student ideas on a class chart.
3. What claims might we make based on this evidence? Remind students that a claim is a statement or conclusion that answers a question based on evidence. Scientists always need to make sure that relevant and sufficient evidence is provided to support a claim. They also provide their reasoning (the big scientific idea or principle that connects the claim and evidence). For example, let’s look at this photograph of a seal (show images and/or videos of a seals from arkive.org). The question is: Why can seals survive in Arctic waters? What do we notice about seals from this image that might help them survive in a cold ocean habitat? Chart student responses. What claim(s) might we be able to make based on this evidence? [Claim: *Seals can live in Arctic waters because they have adaptations for the environment. Example evidence: Their flippers allow them to swim through the water to catch food. The seal’s body is streamlined for swimming. Their fur helps keep them warm.]* What big idea allows us to connect the claim and evidence? *[Adaptations are characteristics that allow an animal to survive in its environment. Getting food and staying warm are both necessary for an animal to live.]*

**DAY 2 – Analyzing Chlorophyll Satellite Images of the Gulf of Maine**

1. Ask students to explain what they did on Day 1 and their findings. Explain that they are now going to make observations about another set of data: satellite images of chlorophyll, again taking notes in their science notebooks. Ask how students think data on chlorophyll might be useful. (*To measure phytoplankton biomass)*. While they are working, remind students to be looking for relationships between the sea surface temperature data and the chlorophyll data (comparing the two sets of satellite images). Ask: “Where on these maps would you expect to see herring?”
2. Bring the class back together and ask each group to share what they notice, and the connections they saw to the sea surface temperature images. Record student ideas on the class chart.
3. Have students read “Seasons in the Sea” by Ann Michelle Morrison, which builds upon what they learned in Lesson 3 about seasonal productivity. Focus question: How does this information help explain what you noticed in the satellite images?
4. Ask students to look at the SST and Chl satellite images again. Ask: What claims can we make now? How has your thinking changed based on what you read? Have students share ideas in small groups and then share out with the whole class.

**DAY 3 – Reading the “Big Picture” (Including Ocean Currents and Bathymetry)**

1. Explain that there are two more factors that they will consider to investigate the big picture of how the physical features of the Gulf of Maine influence where certain species can survive and thrive, what time of year they will reproduce and grow and how their eggs and food get transported. These factors are ocean currents and bathymetry (ocean bottom topography) of the Gulf of Maine.
2. Hand out the Gulf of Maine Bathymetry map. Explain that this shows the ocean bottom topography. Provide an overview of the depth key. Ask students what they notice about the bathymetry of the Gulf of Maine, have them turn and talk with a partner, then share with the whole class.
3. Hand out the Gulf of Maine Currents map. Ask students what they notice about the currents in the Gulf of Maine. Is there any correlation between currents and bathymetry? Share out with the whole class. Explain that the nutrient-rich waters of the Gulf of Maine are fed primarily by the cold, deep Labrador Current, which helps drive the counterclockwise circulation. These currents are influenced by fluctuations in river outflow. Water exits the Gulf mainly through the Great South Channel between Cape Cod and Georges Bank, about three months after entering. The Gulf’s currents have a major impact on marine species because they distribute nutrients, plankton and larvae. They also carry invasive species, toxins and waste.
4. In small groups, ask students to compare the bathymetry and current maps with the SST and Chl satellite images to synthesize what they have already learned and make claims about how the bathymetry and currents affect life in the Gulf of Maine. Share student claims and evidence in a whole class discussion. Create a chart of the claims, evidence and reasoning. Ask: What makes a strong claim?
5. Homework: Explore the Ship Mates website (<http://www.bigelow.org/shipmates>) sections on Biology, Temperature and Salinity to learn more about how ocean productivity is tied to environmental conditions, based on oceanographic cruise data. Then, write a paragraph or blog post that includes at least one claim about how the physical features of the Gulf of Maine influence where certain species can survive and thrive, what time of year they will reproduce and grow, or how their eggs and food are transported. Evidence must be provided from what they have learned.

**DAY 4 – What Happens in the Gulf of Maine During the Year?**

1. Facilitate a science talk around the homework assessment topic. Record student ideas in a class chart.
2. Integrated ELA/Science Project: Based on what you have learned, write a story to explain what is happening in the Gulf of Maine over the course of a year. Be sure to back up your ideas with evidence and describe the role of the physical features of the Gulf of Maine in your story. The story may be presented in written form (story, poster, comic strip), as a Powerpoint presentation or digital story. It also may be acted out. For extra credit, provide two different explanations for what might have caused the changes over the year. You will be expected to share your story with the class.

**Extension:** “When is Dinner Served? Predicting the Spring Phytoplankton Bloom in the Gulf of Maine” by Denise Blaha and Amy Holt Cline, Mary 2012. Earth Exploration Toolbook, <https://serc.carleton.edu/eet/phytoplankton/index.html> .

**Primary Source:** (Adapted from COSEE, [www.cesn.org/cosee\_CD/web/activity/**Ocean**\_Satellites.pdf](http://www.cesn.org/cosee_CD/web/activity/Ocean_Satellites.pdf)*;* and *Exploring Satellite Images* by Amy Cline, <https://www.st.nmfs.noaa.gov/Assets/Nemo/documents/lessons/Lesson_12/Exploring_Sat_Images.pdf>).

**Online Resources:**

* Gulf of Maine Sea Surface Temperature (SST) Satellite Images (2012 monthly composites), University of Maine Satellite Oceanography Data Lab, <http://www.seasurface.umaine.edu/sat_ims.htm>
* Gulf of Maine Chlorophyll Satellite Images (2012 monthly composites), University of Maine Satellite Oceanography Data Lab, <http://www.seasurface.umaine.edu/sat_ims.htm>
* Morrison, Ann Michelle. “Seasons in the Sea.” Earth Exploration Toolbook, <http://serc.carleton.edu/eet/phytoplankton/going_further.html>.
* Gulf of Maine map, University of New Hampshire, photo digital bathymetry map by Ed Roworth and Rich Signell of the U.S. Geological Survey, courtesy of the Regional Association for Research on the Gulf of Maine, <http://www.eos.unh.edu/Spheres_0313/graphics/spring13_pics/gom_lg.jpg>
* Gulf of Maine Bathymetry map, Gulf of Marine Educators Association (http://www.gommea.org/about-the-gulf/physical-characteristics/bathymetry.html), Credit: Base map data from USGS (<http://pubs.usgs.gov/of/1998/of98-801/bathy/index.htm>), image created by Gulf of Maine Area Program, Census of Marine Life.
* Gulf of Maine Currents map, Maine: An Encyclopedia, <http://maineanencyclopedia.com/gulf-of-maine>, Credit: Ocean Modeling Group, School of Marine Sciences, University of Maine.
* Argument Writing in Science Rubric (Grades 9-10), <http://the-curious-scientist.weebly.com/curriculum.html>
* Argument Writing in Science Rubric (Grades 11-12), <http://the-curious-scientist.weebly.com/curriculum.html>

**Print Resources:** Cerullo, Mary. *Sea Soup-Phytoplankton.* Gardiner, Maine: Tilbury House Publishers, 1999.

# Lesson 5: Introduction to Stellwagen Bank

**Brief Overview of Lesson:** So far in this unit, students have been delving into the relationships between the physical features of the Gulf of Maine and the organisms that live there. In the next three lessons, students will use what they have learned to explore ocean ecosystems in more depth. This lesson focuses on the Stellwagen Bank National Marine Sanctuary located within the Gulf of Maine. Students will learn how this area became a National Marine Sanctuary and explore its unique physical and biological features, as well as some of the problems that it faces.

**Prior Knowledge Required:** Knowledge of ecosystems

**Estimated Time:** Two 50-minute classes

**Standard(s)/Unit Goal(s) to be Addressed in This Lesson:**

* **HS-ESS3-3** Illustrate relationships among management of natural resources, the sustainability of human populations, and biodiversity. Clarification Statements: Examples of factors related to the management of natural resources include costs of resource extraction and waste management, per capita consumption, and the development of new technologies. Examples of factors related to human sustainability include agricultural efficiency, levels of conservation, and urban planning. Examples of factors related to biodiversity include habitat use and fragmentation, and land and resource conservation.
* **HS-LS2-7** Analyze direct and indirect effects of human activities on biodiversity and ecosystem health, specifically habitat fragmentation, introduction of non-native or invasive species, overharvesting, pollution, and climate change. Evaluate and refine a solution for reducing the impacts of human activities on biodiversity and ecosystem health. \* Clarification Statement: Examples of solutions can include captive breeding programs, habitat restoration, pollution mitigation, energy conservation, and ecotourism.

**Big Ideas:**

* Stellwagen Bank National Marine Sanctuary is a unique ecosystem that is vital to the health of our ocean resources.
* The unique biodiversity in Stellwagen Bank is caused by the ways that the physical environment (e.g., ocean temperature, bathymetry, and currents) interact to provide optimum conditions for life.
* Living and nonliving things in the Stellwagen Bank National Sanctuary are interconnected. If one species is affected by human actions, many other living things in the ecosystem are also affected.
* Human actions have placed tremendous pressures on the Stellwagen Bank ecosystem, but actions are being taken to resolve these pressures.

**Essential Question(s) Addressed in This Lesson:**

* What are the components of the Stellwagen Bank ecosystem and how do they interact with each other?
  + What are some of the major problems associated with protecting this resource?

**Objective:**

**Students will be able to…**

* Describe the components of the Stellwagen Bank ecosystem and explain why the Stellwagen Bank was designated as a marine protected area.
* Construct a claim based on evidence about the relationship between the management of natural resources, the sustainability of human populations, and biodiversity.
* Analyze direct and indirect effects of human activities on biodiversity and ecosystem health.

**Targeted Academic Language:** biodiversity,habitat, marine sanctuary

**Anticipated Student Preconceptions/Misconceptions:**

* Students may not be aware of the interconnectedness of physical and biological components of the ocean system.

**Instructional Materials/Resources/Tools:**

* Maps and diagrams: NOAA Our National Sanctuaries map, Gerry E. Studds Stellwagen Bank National Marine Sanctuary map
* Readings:
  + NOAA National Marine Sanctuaries Frequently Asked Questions
  + “Forward” from *Stellwagen Bank* by Nathalie Ward
  + “The Pageant of Life” from *Stellwagen Bank* by Nathalie Ward
  + “Site History and Resources” from the National Marine Sanctuary Condition Report
  + “Pressures on the Sanctuary” from the National Marine Sanctuary Condition Report
  + “The Stellwagen Bank Ecosystem” from *Stellwagen Bank* by Nathalie Ward
* Science notebooks
* Projector/computer/internet access

**Instructional Tips for Teacher:**

* At this time, the most current NOAA Condition Report for Stellwagen Bank is dated 2007. The sections to that report that are referenced here include useful information. If you’d like to access more recent information, a 2013 National Marine Sanctuary System Condition Report is available (<http://sanctuaries.noaa.gov/science/condition/welcome.html>). However, the information provided in this document is more general and only a small amount of information specific to Stellwagen Bank is provided.
* For information on facilitating science talks: Talk Science Primer, TERC (<http://inquiryproject.terc.edu/shared/pd/TalkScience_Primer.pdf>), Goals for Productive Discussions and Nine Talk Moves, TERC (<http://inquiryproject.terc.edu/assessment/Goals_and_Moves.cfm>),

**Assessment**

* Formative**:** “Why do you think we need to do to protect our ocean resources? Explain your thinking.”
* Blog post homework assignment: Based on the information you gathered (in class and from homework readings) explain why you think Stellwagen Bank was designated as a National Marine Sanctuary. Provide evidence to support your ideas.

**Lesson Details:**

**DAY 1 – National Marine Sanctuaries**

1. Explain that the class will be learning about the Stellwagen Bank National Marine Sanctuary, part of a large-scale effort to protect our ocean resources. Ask students to write a few sentences answering the question: “Why do you think we need to do to protect our ocean resources?” Have students turn and talk, then share ideas in the whole group.
2. Project the Our National Marine Sanctuaries satellite map and tell students that the map shows federally protected waters called National Marine Sanctuaries. The National Marine Sanctuary Program was established in 1972, exactly 100 years after the first national park was created, to preserve our marine treasures. Since then 13 National Marine Sanctuaries and one Marine National Monument have been created—they represent a wide variety of ocean environments and ecosystems (deep ocean areas, coral reefs, whale migration corridors, deep sea canyons, and underwater archeological sites).
3. Class brainstorm: What do you think the term “marine sanctuaries” means? Explain that they will find out more about the characteristics of these areas and why they are in need of special protection.
4. Ask students to read the National Oceanic and Atmospheric Administration’s (NOAA’s) National Marine Sanctuaries Frequently Asked Questions and/or view the NOAA National Marine Sanctuaries website (<http://oceanservice.noaa.gov/oceans/sanctuaries/>) for an overview of National Marine Sanctuaries. The focus question for the reading is: Why are National Marine Sanctuaries important?
5. View the short NOAA video Earth is Blue: Your National Marine Sanctuary System (3:10 minutes) (<http://sanctuaries.noaa.gov/videos/sanctuary-overview.html>).
6. Ask students to turn and talk. Focus question: Why are National Marine Sanctuaries important? Share their ideas with the entire class.
7. Refer back to the map of National Marine Sanctuaries and point out that the Stellwagen Bank National Sanctuary is off the coast of Massachusetts. Show the NOAA Stellwagen Bank map.
8. View: A Sanctuary Worth Saving: Stellwagen Bank (5:04 minutes) (<https://www.youtube.com/watch?v=mJRfyAJFfMY>)
9. Homework readings:

* “Forward” and “The Pageant of Life,” “from *Stellwagen Bank: A Guide to the Whales, Sea Birds, and Marine Life of the Stellwagen Bank National Marine Sanctuary*, Nathalie Bank, 1995, Camden: ME, Down East Books. (out of print)
* “Stellwagen Bank National Marine Sanctuary Site History and Resources” and “Pressures on the Sanctuary: from the *Stellwagen Bank 2007 Condition Repor*t.

Focus questions: 1) What are some of the unique features of Stellwagen Bank? 2) What kinds of habitats are found there? 3) What key species live there? and 4) What are some of the major problems faced in protecting this resource? Take notes or create a concept map to record what you learn.

1. Blog post homework assignment: Based on the information you gathered, explain why you think that Stellewagen Bank was designated as a National Marine Sanctuary. Provide evidence to support your ideas. Comment on the posts of two other classmates—focusing on ways to extend their thinking.

**DAY 2 – Stellwagen Bank**

1. Facilitate a science talk focusing on the homework focus question: Why do you think this area of the ocean was designated as a National Marine Sanctuary? What do you think are the relationships between how the natural resources of Stellwagen Bank and human populations?[For this activity, students should be seated in a circle so that everyone can see everyone else. The teacher should pose the question and then let students respond to each other—following discussion rules that the class has created ahead of time (e.g., talk respectfully to one another, make eye contact, respect air time, etc.).]
2. Homework: Tell the class that in the next class, they will focus on the Stellwagen Bank ecosystem to explore the essential question: “How do the living and nonliving things in the ocean system depend on each other?” For homework, read the “The Stellwagen Bank Ecosystem.” Focus questions: 1) How do the physical features of the Stellwagen Bank (e.g., water temperature, salinity, geology, etc.) affect the living things that live there? 2) How are living and nonliving things connected in the Stellwagen Bank ecosystem? Be prepared to discuss in class.

**Resources:**

* NOAA, Office of National Marine Sanctuaries, Our National Marine Sanctuaries map, <http://montereybay.noaa.gov/materials/maps.html>
* NOAA, Office of National Marine Sanctuaries, “Frequently Asked Questions,” <http://sanctuaries.noaa.gov/about/faqs/>
* Gerry E. Studds Stellwagen Bank National Marine Sanctuary map, <http://stellwagen.noaa.gov/pgallery/maps.html>
* “Forward,” *Stellwagen Bank: A Guide to the Whales, Sea Birds and Marine Life of the Stellwagen Bank National Marine Sanctuary,* Nathalie Ward. Camden, ME: Down East Books, 1995. [out of print]
* “The Pageant of Life,” *Stellwagen Bank: A Guide to the Whales, Sea Birds and Marine Life of the Stellwagen Bank National Marine Sanctuary,* Nathalie Ward. Camden, ME: Down East Books, 1995 [out of print]
* “The Stellwagen Bank Ecosystem,” *Stellwagen Bank: A Guide to the Whales, Sea Birds and Marine Life of the Stellwagen Bank National Marine Sanctuary,* Nathalie Ward. Camden, ME: Down East Books, 1995 [out of print]
* NOAA, Office of National Marine Sanctuaries, “Site History and Resources,” Stellwagen Bank 2007 Condition Report, <http://sanctuaries.noaa.gov/science/condition/sbnms/>
* NOAA, Office of National Marine Sanctuaries, “Pressures on the Sanctuary,” Stellwagen Bank 2007 Condition Report, <http://sanctuaries.noaa.gov/science/condition/sbnms/>

# Lesson 6: Stellwagen Bank Ecosystem

**Brief Overview of Lesson:** Students research and create a visual representation of a Stellwagen Bank food web, explaining the connections between living and nonliving things, and how the physical environment affects the marine species that live there. Students synthesize their knowledge to predict what would happen if one or two components of the food web disappeared or decreased in numbers. Finally, based on what they have learned, students create a written argument about the interconnection of living and nonliving things in the Stellwagen Bank ecosystem.

**Prior Knowledge Required:** Ecosystems, models

**Estimated Time:** Three 50-minute classes

**Standard(s)/Unit Goal(s) to be Addressed in This Lesson:**

* **HS-LS2-6** Analyze data to show ecosystems tend to maintain relatively consistent numbers and types of organisms even when small changes in conditions occur but that extreme fluctuations in conditions may result in a new ecosystem. Construct an argument supported by evidence that ecosystems with greater biodiversity tend to have greater resistance to change and resilience. Clarification Statement: Examples of changes in ecosystem conditions could include modest biological or physical changes, such as moderate hunting or a seasonal flood; and extreme changes, such as volcanic eruption, fires, the decline or loss of a keystone species, climate changes, ocean acidification, or sea level rise.
* **W.9-10.1** Write arguments (e.g., essays, letters to the editor, advocacy speeches) to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.
* **W.11-12.1** Write arguments (e.g., essays, letters to the editor, advocacy speeches) to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.

**Big Ideas:**

* The unique biodiversity in Stellwagen Bank is possible due to the ways that the features of the physical environment (e.g., ocean temperature, ocean bottom topography or bathymetry, and currents) interact to provide optimum conditions for life.
* Living and nonliving things in the Stellwagen Bank National Sanctuary are interconnected. If one species or the physical environment is affected by human actions, many living things in the ecosystem are also impacted.
* Human actions have placed tremendous pressures on the Stellwagen Bank ecosystem, but actions are being taken to resolve these pressures.

**Essential Question(s) Addressed in This Lesson:**

* What are the components of the ocean system and how do they interact with each other?

**Objectives:**

**Students will be able to…**

* Gather evidence to support the claim that extreme fluctuations within an ecosystem may have significant effects.
* Create a model of a Stellwagen Bank food web that explains the connections between living and nonliving things in the Stellwagen ecosystem.
* Synthesize knowledge to predict what would happen if one or more components of the food web disappeared or decreased in numbers.
* Create a written argument about the interconnections of living and nonliving things in the Stellwagen Bank ecosystem.

**Targeted Academic Language:** consumer, decomposer, ecosystem, food web, producer, species

**Anticipated Student Preconceptions/Misconceptions:**

* Students may not be aware of the widespread impact that changes in marine species and the physical environment have on the rest of the ocean system.

**Instructional Materials/Resources/Tools:**

* Food Web Activity Resources: Stellwagen Bank Photo Cards, Stellwagen Bank Food Web Worksheet, Stellwagen Bank Food Web Key (teacher reference only)
* Rubrics: Argument Writing in Science Rubric (Grades 9-10), Argument Writing in Science Rubric (Grades 11-12)
* Science notebooks
* Optional internet access for students

**Instructional Tips for Teacher:**

* Lamination of the Stellwagen Bank Photo Cards is suggested in order to protect them for multiple uses. In addition to using them to create food webs, how many other uses can you think of? (What about creating similar sets for other National Marine Sanctuaries and comparing the types of living things/food webs?)
* Species included in the Stellwagen Bank Photo Cards: Atlantic lobster, Atlantic Bluefin tuna, Atlantic cod, Atlantic herring, Atlantic sea scallop, northern gannet, harbor (common) seal, leatherback sea turtle, lion’s mane jellyfish, long-finned squid, North Atlantic right whale, ocean quahoag, phytoplankton, zooplankton. Each group should also have a Sunlight card and a Humans card.
* See the Stellwagen Food Web Key for information on possible food webs that students may create (teacher resource only!)

**Assessment**

* Formative**:** How do the physical features of the Stellwagen Bank (e.g., water temperature, salinity, geology, etc.) affect the living things that live there? 2) How are living and nonliving things connected in the Stellwagen Bank ecosystem? (Group discussions based on the homework reading-“The Stellwagen Bank Ecosystem.”)
* Summative: Create awritten argument that makes a claim about the interconnections of living and nonliving (abiotic) things in the Stellwagen Bank ecosystem. Focus question: What happens when one of the components of an ecosystem changes drastically? Use evidence gathered during the Stellwagen Bank food web activity. Make sure to include your reasoning.

**Lesson Details:**

**DAY 1 – The Stellwagen Bank Ecosystem**

1. Explain that students have had a chance to learn and think about the unique features of Stellwagen Bank (including the habitats and the kinds of living things that are found there) and some of the problems that it faces. Now, the class will focus on the Stellwagen Bank ecosystem to explore the essential question: “How do the living and nonliving things in the ocean system depend on each other?”
2. In small groups, ask students to discuss the focus questions from the homework reading (“The Stellwagen Bank Ecosystem”). Focus questions: 1) How do the physical features of the Stellwagen Bank (e.g., water temperature, salinity, geology, etc.) affect the living things that live there? 2) How are living and nonliving things connected in the Stellwagen Bank ecosystem? (A whole group science talk can then be facilitated to share ideas.)
3. Explain that they are going to do some research on specific living things that live in Stellwagen Bank and then create a visual food web (illustrating the connections between living and nonliving things). Assign students into groups of 8. Give each student two Stellwagen Bank Ecosystem Species photo cards. (Each student should have different species/features.) Ask the students to individually research their species/feature to find out what they eat, what eats them, and/or how they affect living things in the Stellwagen Bank ecosystem. Students should record this information on the Stellwagen Bank Species/Feature Research worksheet or in their science notebooks. Suggested online resources:

* NOAA. “FishWatch Seafood Profiles.” <https://www.fishwatch.gov/>
* ARKive. <http://www.arkive.org>.

If students need more time to research, they can finish gathering information as homework.

**DAY 2 – Stellwagen Bank Food Webs**

1. Using the information that they gathered the day before (and/or as homework), each team will then create a basic Stellwagen Bank food web on a chart paper, arranging and then taping their species/feature cards on the paper and connecting them with arrows. (The arrows point in the direction of what’s being eaten to who’s eating it). Have students do a gallery walk, writing comments/suggestions/questions on post-its to leave on each chart.
2. In groups, discuss: What would happen if one or more species in the food web were removed from the ecosystem? Would the effect be more serious depending on the type of species that’s removed? Make claims based on evidence (connected by reasoning). If necessary, review the claims based on evidence background and rubric covered in Lesson 4.
3. Ask students to present their food web to the class. They should explain the connections between their species/features and share their predictions of what will happen if one or more components of their food web disappear or decrease in numbers. Focus question for the audience: How are the food webs alike? Different?

**DAY 3 – Comparing Food Webs**

1. Finish group presentations. Facilitate a science talk: How are the food webs alike? Different? What are the roles of different species in the food webs? (*producers, consumers, decomposers)* Are these same roles found in each food web? Provide evidence to support your claims.
2. Argument Writing Homework Assignment: Based on what you have learned, make a claim about the interconnection of living and nonliving things in the Stellwagen Bank National Marine Sanctuary. Back up your claim with evidence that you have gathered or learned during class. Be sure to include your reasoning (what connects the claim with your evidence?) Use the argument writing rubric as a guide for determining what is expected.

# Lesson 7: Comparing Ocean Ecosystems

**Brief Overview of Lesson:** Students work in groups to research the ecosystems of other National Marine Sanctuaries in order to investigate the common features of all ocean systems. They also determine how the goals of a National Marine Sanctuary relate to the individual ecosystem found there. Their findings are presented in a poster or digital story and the lesson culminates with a science talk focusing on the ways that the goals of each sanctuary match the individual needs of the ecosystem.

**Prior Knowledge Required:** Background on Marine National Sanctuaries (from Lesson 5)

**Estimated Time:** Two 50-minute classes

**Standard(s)/Unit Goal(s) to be Addressed in This Lesson:**

* **HS-ESS3-3** Illustrate relationships among management of natural resources, the sustainability of human populations, and biodiversity. Clarification Statements: Examples of factors related to the management of natural resources include costs of resource extraction and waste management, per capita consumption, and the development of new technologies. Examples of factors related to human sustainability include agricultural efficiency, levels of conservation, and urban planning. Examples of factors related to biodiversity include habitat use and fragmentation, and land and resource conservation.
* **W.9-10.1** Write arguments (e.g., essays, letters to the editor, advocacy speeches) to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.
* **W.11-12.1** Write arguments (e.g., essays, letters to the editor, advocacy speeches) to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.

**Big Ideas:**

* Ocean ecosystems are similar in many ways.
* The goals of National Marine Sanctuaries and other marine protected areas match the individual needs of the ecosystem found there.
* More large-scale efforts, like the creation of additional marine protected areas are needed to protect our ocean resources.

**Essential Question(s) Addressed in This Lesson:**

* What are the components of the ocean system and how do they interact with each other?
  + What are the common features of all ocean ecosystems? What are the differences?
  + How do the goals of the National Marine Sanctuaries match the individual needs of their ecosystems?
  + Why are more marine protected areas needed?

**Objectives:**

**Students will be able to…**

* Identify similarities and differences of features of different ocean ecosystems in order to explain the relationships among management of natural resources, the sustainability of human populations and biodiversity.
* Explain how the goals of each sanctuary match the individual needs of the ecosystem found there.
* Create a written argument about the factors that should be considered when selecting new sanctuary areas in the United States and other countries.

**Targeted Academic Language:** marine protected area (MPA)

**Anticipated Student Preconceptions/Misconceptions:**

* Students may not think that all ocean ecosystems have similar components.

**Instructional Materials/Resources/Tools:**

* Map: National Marine Sanctuary Map,
* Student worksheets: National Marine Sanctuary Student Project Worksheet, National Marine Sanctuary For Further Understanding Worksheet
* Rubrics*:* Argument Writing in Science Rubric (Grades 9-10), Argument Writing in Science Rubric (Grades 11-12)
* Projector/computer
* Science notebooks
* Access to internet
* Video: PBS DVD *Jean-Michel Cousteau Ocean Adventures:* *America’s Underwater Treasures* (optional)

**Instructional Tips for Teacher:**

* Argument writing rubric can be used for summative assessment. Be sure to share the rubric with students ahead of time. If necessary, review the instruction on claims, evidence and reasoning from Lesson 4.
* If access to the Internet is not available for all students, the teacher can print out copies of website pages for students to review.

**Assessment**

* Formative**:** “How are all ocean ecosystems alike? How are they different? Explain your thinking.”
* Project: Group posters/presentations on National Marine Sanctuaries
* Authentic Performance Assessment: An international group has called on the world to set aside 10 percent of coastal and marine waters as protected areas by 2020. As of 2013, only a little over 1% of coastal and marine waters are protected. Based on what you have learned about the physical environment, ecosystems, and problems associated with National Marine Sanctuaries, make a claim about the factors that you think should be considered when selecting new sanctuary areas in the United States and other countries. Explain why you think these factors are important, providing evidence from what you have learned.

**Lesson Details:**

**DAY 1 – National Marine Sanctuary Research**

1. Written pre-assessment (in science notebooks or as a blog post): “How are all ocean ecosystems alike? How are they different? Explain your thinking.” Ask students to share their ideas in small groups, then share with the whole class.
2. Now that the class finished an in-depth study of the Stellwagen National Marine Sanctuary, they are going to research the other marine sanctuaries and compare how they are similar to and different from Stellwagen Bank. They will work in groups to do their research and then create a poster, digital story, Prezi or other type of presentation to share with the class. Project the Our National Marine Sanctuaries map to show students where the other sanctuaries are. Explain that National Marine Sanctuaries are part of a network of worldwide marine protected areas (MPAs).
3. Divide the class into 12 groups and assign each group one of the remaining national marine sanctuaries (other than Stellwagen Bank). Pass out the National Marine Sanctuaries Student Project worksheet. Tell students that they will be conducting web-based research using several sources such as:

* NOAA’s Encyclopedia of the National Marine Sanctuaries (<http://www8.nos.noaa.gov/onms/park/>)
* Guide to America’s National Marine Sanctuaries, Jean-Michel Cousteau: Ocean Adventures, (<http://www.pbs.org/kqed/oceanadventures/episodes/treasures/guide/home.html>)

(If available, students can also view the segment of the PBS DVD *America’s Underwater Treasures* that applies to their sanctuary.)

Tell students that they should be able to describe the goals of their sanctuary as they relate to the individual needs of the ecosystems found there. This information (along with the information on the project worksheet) should be presented in their poster, digital story, Prezi, etc.

If students don’t finish their project in class, assign it for homework.

**DAY 2 – Comparing Sanctuaries and Their Ecosystems**

1. If students have created posters, place them around the room and have students do a gallery walk, followed by the presentations. During the presentations, students should take notes in order to complete the National Marine Sanctuaries: The Big Picture worksheet, which asks them to compare and contrast their sanctuary with the other sanctuaries. If students have created digital stories or other types of presentations, ask the audience to take notes while watching.
2. Facilitate a class science talk focusing on how the sanctuaries are alike and how they are different. Guide the discussion toward how the goals of each sanctuary match the individual needs of the ecosystems found there. Students should make claims based on their evidence. Encourage students to question and critique the claims and evidence of others (in a respectful way).
3. Explain that they have learned about what is being done to protect ocean resources in the United States. Environmental groups and scientists are trying to encourage other areas to create more marine protected areas as well.
4. Summative Assessment: An international group has called on the world to set aside 10% of coastal and marine waters as marine protected areas by 2020. As of 2013, only a little over 1% of coastal and marine waters are protected.

Based on what you have learned about the physical environment, ecosystems, and problems associated with National Marine Sanctuaries, craft a written argument outlining the factors that you think should be considered when selecting new sanctuary areas in the United States and other countries. Explain why you think these factors are important, providing evidence from what you have learned.

**Sources**:

* Exploring National Marine Sanctuaries lesson developed by NOAA’s National Marine Sanctuary Program (copy and paste link) (<https://mass.pbslearningmedia.org/resource/pbs_org14_jmcoa_sci_19/jean-michel-cousteau-ocean-adventures-lesson-plan-exploring-national-marine-sanctuaries/#.Wyu9nlKWzIU>) and the National Geography Society
* PBS. “Exploring National Marine Sanctuaries” lesson. <http://www.pbs.org/kqed/oceanadventures/educators/#lessonplans>

**Extension:** Marine Sanctuary Architect Activity/Assessment[Modified based on “Threats to Ocean Life: Can Marine Sanctuaries Help?” National Geographic, <http://education.nationalgeographic.com/archive/xpeditions/lessons/14/g68/seasthreats.html?ar_a=1>

The World Wildlife Fund (WWF) has created a map of freshwater and marine ecoregions of the world that they have designated as the most critical areas for conservation due to their exceptional biodiversity (Global 200 download, <https://www.worldwildlife.org/publications/global-200>)

Pick an ecoregion from the WWF Global 200 list and write a proposal for a marine sanctuary in that area. Your proposal should include:

* Where the sanctuary will be located, and which country or countries would be involved. Explain why you chose this location
* How a sanctuary might benefit this area
* Who might be in favor of the sanctuary and who might be opposed to the sanctuary
* What the limitations of this sanctuary in protecting the marine species that live there might be
* What problems that begin outside the sanctuary might be difficult to control

**Resources:**

* NOAA, Office of National Marine Sanctuaries, Our National Marine Sanctuaries map, <http://montereybay.noaa.gov/materials/maps.html>
* National Marine Sanctuaries Student Project Worksheet. PBS, “Exploring National Marine Sanctuaries” lesson (copy and paste link). <https://mass.pbslearningmedia.org/resource/pbs_org14_jmcoa_sci_19/jean-michel-cousteau-ocean-adventures-lesson-plan-exploring-national-marine-sanctuaries/#.Wyu9nlKWzIU>
* National Marine Sanctuaries For Further Understanding Worksheet. PBS, “Exploring National Marine Sanctuaries” lesson (copy and paste link). <https://mass.pbslearningmedia.org/resource/pbs_org14_jmcoa_sci_19/jean-michel-cousteau-ocean-adventures-lesson-plan-exploring-national-marine-sanctuaries/#.Wyu9nlKWzIU>
* PBS Home Video. *Jean-Michel Cousteau Ocean Adventures: America’s Underwater Treasures*. PBS, 2006. (optional)

# Lesson 8: Human Impacts on the Ocean-Bycatch

**Brief Overview of Lesson:** Students learn about the types of fishing gear that are used to harvest seafood and their impact on marine species and the environment. They are introduced to the problems associated with bycatch (via a hands-on simulation and videos), then research innovative designs (bycatch reduction devices) that are being tested to reduce bycatch. Finally, students (working in groups) will design a bycatch reduction device (using the Engineering Design Process) to reduce bycatch of a specific species for one type of fishing gear. During this process, they will consider the physical features, habitat and behaviors of the target species and the bycatch species. The final product will be a drawing or model of the design, along with an explanation of the basis of the design (what criteria were considered), how it works, and how the prototype would be tested. A poster and presentation (or digital story) will be created to convince a group of fishermen (the class) to install/implement their device.

**Prior Knowledge Required:** Engineering Design Process

**Estimated Time:** Six 50-minute classes

**Standard(s)/Unit Goal(s) to be Addressed in This Lesson:**

* **HS-LS2-6** Analyze data to show ecosystems tend to maintain relatively consistent numbers and types of organisms even when small changes in conditions occur but that extreme fluctuations in conditions may result in a new ecosystem. Construct an argument supported by evidence that ecosystems with greater biodiversity tend to have greater resistance to change and resilience. Clarification Statement: Examples of changes in ecosystem conditions could include modest biological or physical changes, such as moderate hunting or a seasonal flood; and extreme changes, such as volcanic eruption, fires, the decline or loss of a keystone species, climate changes, ocean acidification, or sea level rise.
* **HS-LS2-7** Analyze direct and indirect effects of human activities on biodiversity and ecosystem health, specifically habitat fragmentation, introduction of non-native or invasive species, overharvesting, pollution, and climate change. Evaluate and refine a solution for reducing the impacts of human activities on biodiversity and ecosystem health. \* Clarification Statement: Examples of solutions can include captive breeding programs, habitat restoration, pollution mitigation, energy conservation, and ecotourism.
* **HS-ETS1-3** Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, aesthetics, and maintenance as well as social, cultural, and environmental impacts.

**Big Ideas:**

* Fishing gear that is not selective to the target species has a significant impact on other marine species.
* Some types of fishing gear are very destructive to the marine environment.
* Scientists, engineers and fishermen are designing and implementing innovative bycatch reduction devices to minimize the impact of bycatch on non-target marine species.

**Essential Question(s) Addressed in This Lesson:**

* How do humans impact the ocean system?
* How can ocean resources be managed to reduce human impact, make the use of ocean resources by humans sustainable and maintain the diversity of the ocean system?
  + How do different types of fishing gear affect marine species and the environment?
  + What is bycatch and how does it impact marine species?
  + What are scientists and fishermen doing to minimize bycatch?
  + What are the factors and steps involved in designing bycatch reduction devices?

**Objectives:**

* Analyze direct and indirect effects of human activities on biodiversity and ecosystem health.
* Gather evidence to support the claim that extreme fluctuations within an ecosystem may have significant effects.
* Describe the impact of different fishing gear on marine species and the environment.
* Explain what bycatch is and why it is a serious problem.
* Design a bycatch reduction device for a specific type of fishing gear to reduce bycatch of a specific species.

**Targeted Academic Language:** bycatch, bycatch reduction devices, engineering design process, fishing gear, target species

**Anticipated Student Preconceptions/Misconceptions:**

* Fishermen don’t catch enough bycatch to have to change their fishing methods.
* There are so many fish in the oceans that bycatch does not impact the ocean system.

**Instructional Materials/Resources/Tools:**

* Teacher Background: Bycatch Teacher Background
* Readings: “What is Bycatch?” (Consortium for Wildlife Bycatch Reduction), “A Net Loss: The Effects of Bycatch” (PBS, Jean-Michel Cousteau Ocean Adventures), Types of Fishing Gear List, “Fishing Gear is Altered to Ease Collateral Costs to Marine Life” (*New York, Times* August 22, 2011) <http://www.nytimes.com/2011/08/23/science/23catch.html?pagewanted=all&_r=0>, “Fishing Technique Modifications” (Consortium for Wildlife Bycatch Reduction) <http://www.bycatch.org/research/consortium/fishing-gear-modifications>
* Bycatch Simulation:
* 4-5 tablespoons sprinkles
* One bag orzo pasta
* One small bag of small elbow pasta
* One small bag of large elbow or ziti pasta
* One bag of Goldfish crackers
* One bag of Goldfish pretzels
* One “net” per group
* One large shallow container
* Student Worksheets/Handouts: Fisheries Catch Record Sheet, Fishing Gear Research Worksheet, Bycatch Reduction Device Worksheet, Steps of the Engineering Design Process (DESE), Bycatch Reduction Device Engineering Design Worksheet.
* Science notebooks
* Projector/computer/internet access/speakers

**Instructional Tips for Teacher:**

* For this lesson, students will need access to the internet.
* At the beginning of the lesson, you will need to ask students to bring in recycled materials for use in the bycatch reduction engineering challenge project.
* The teacher will need to prepare for the bycatch simulation ahead of time. For each student group, prepare a paper cup that contains a mixture of “seafood” species (sprinkles, small pasta, large pasta, Goldfish crackers). The number of each type of “seafood” should be similar in all cups. Create a key that shows the “seafood” that each type of food represents.

**Assessment**

* Formative**:** What do you think you know about how different ways fishermen catch seafood? How do these fishing methods affect the environment? Explain your thinking.
* Day 2 homework assignment/blog post: How do current fishing methods harm marine life and the environment? Be sure to back up your claims with specific evidence.
* Day 3 Homework assignment/blog post: Based on what we know so far, how do you think bycatch affects marine ecosystems? Provide evidence to support your claim.
* Day 4 Homework assignment/blog post: If you were going to design a bycatch reduction device, what factors do you think would be important? Why?
* Poster/Presentation: Poster and presentation of engineering design of a bycatch reduction device prototype (drawing or model). Explain the basis of the design, how it works, and how it might be tested.

**Lesson Details:**

**DAY 1 – Fishing Gear**

Introduction (20 minutes)

1. Have students write their ideas on the following questions individually in their science notebooks: “What do you think you know about how different ways fishermen catch seafood? How do these fishing methods affect the environment?” Ask students to turn and talk to a partner about these questions, (Alternatively, students could write their ideas on sticky-notes and them add them to two charts—one for each focus question.) (In any case, students will reflect on these initial ideas at the end the lesson, so they need to be recorded and saved.)
2. Explain that in this lesson, the class will be exploring current fishing methods and their impact on marine species and the environment. They’ll also be learning how scientists and fishermen are working to improve seafood harvesting methods and will have a chance to do a culminating Engineering design challenge themselves to solve a real-world problem.
3. Tell students that this lesson focuses on bycatch, which is affecting the population of many marine species. Have students read “What is Bycatch?” (Consortium for Wildlife Bycatch Reduction) and/or “A Net Loss: The Effects of Bycatch.” They can also listen to: Impacts of Bycatch on Ocean Life (WGBH (1:30 minutes), <http://www.pbslearningmedia.org/resource/490d1f70-77d7-48c2-a2d4-047bd21fa44c/490d1f70-77d7-48c2-a2d4-047bd21fa44c/>). Turn and talk with a partner. Then discuss as a whole class.
4. Explain that they are now going to learn more about specific seafood harvesting methods, including their impact on bycatch.

Fishing Gear (30 minutes)

1. Tell students that they are going to learn about the many different ways that fishermen harvest seafood. Project the Types of Fishing Gear List, explaining the three categories (static, mobile and encircling).
2. Divide the class into groups of 2-3. Assign each group a type of fishing gear. Explain that each group will become experts on their type of fishing gear by researching how the method works, what type of fish it is designed to catch, how the design is based on the characteristics/behaviors of the target seafood, and the advantages and disadvantages of the method (from the perspective of the fish and the perspective of the fishermen). The end result will be a poster or chart.
3. Explain the Fishing Gear Research worksheet and encourage students to add more information that might answer other questions they have about their type of fishing gear. Have students research their fishing method using resources such as:

* Fishing and Farming Methods, Monterrey Bay Aquarium Seafood Watch, <http://www.seafoodwatch.org/ocean-issues/fishing-and-farming-methods>
* How We Fish Matters: Addressing the Ecological Impacts of Canadian Fishing Gear, seachoice.org, <http://www.howwefish.ca>

Students can finish their work as homework if necessary.

**DAY 2 – Affect of Fishing Methods on Marine Life and the Environment**

1. Each group will share their poster/chart with the class and, if possible, post their information and visuals on the class website/blog. During the presentations, have students fill in a class chart recording the following information for each fishing method: brief description of how it is designed to catch certain types of fish, bycatch potential/animals affected, and potential to harm the environment. (In lieu of presentations, facilitate a gallery walk. Students can gather information from looking at the posters/charts and then contribute to creating the class chart.)
2. Facilitate a science talk focusing on the homework prompt: “How do current fishing methods harm marine life and the environment?” Some other questions that can be discussed:

* What surprised you the most about your research findings?
* Which fishing method is the least harmful to the environment? To non-targeted species? Why?
* Which fishing method is the most harmful in terms of bycatch? Why?
* Why are fishermen using fishing gear that harm the environment and have significant bycatch potential?

1. Homework: Students will analyze the information on the class chart and write an essay based on the following prompt: “How do current fishing methods harm marine life and the environment? Be sure to back up your claims with specific evidence.” (This could also be a blog post assignment.)

**DAY 3 – Bycatch Simulation**

Materials:

* 4-5 tablespoons sprinkles (phytoplankton)
* One bag orzo pasta (small fish)
* One small bag of small elbow pasta (Pacific Big Eye tuna juveniles -target fish species)
* One small bag of large elbow or ziti pasta (Pacific Big Eye tuna adults - target fish species)
* One bag of Goldfish crackers (sharks)
* One bag of Goldfish pretzels (sea turtles)
* One “net” per group (small “nets” of different size mesh)
* One large shallow container (the ocean)
* Laptops/access to the Internet
* Fisheries Catch Record Sheet

Teacher Preparation:

For each student group, prepare a paper cup that contains a mixture of “seafood” species (sprinkles, small pasta, large pasta, Goldfish crackers). The number of each type of “seafood” should be similar in all cups. Create a key that shows the “seafood” that each type of food represents.

Learning Activity:

1. Briefly review ideas from the homework assignment: How do current fishing methods harm marine life and the environment?
2. Explain that the class will be doing a hands-on activity to simulate bycatch and its effect on marine species. We will be creating a model to do this. The shallow container represents the ocean with a variety of species living in it. Tell students which food represents which species and give them the key.
3. Divide the class into groups of 3-4 students. Before students begin “fishing” have them explore the NOAA FishWatch site ([www.fishwatch.gov](http://www.fishwatch.gov)) to learn more about Pacific bigeye tuna and the fishing methods used to catch them.
4. Tell students they are fishermen who are going to fish for Pacific bigeye tuna (ziti pasta). Give each group a “net” and tell them the nets represent a purse seine. Ask the purse seine experts from the fishing gear research activity to review how a purse seine works for the class. (*It is a type of net with a drawstring-like mechanisms that is dragged along a purse seiner boat. Purse seines target schooling fish, such as Pacific bigeye tuna, and scoop them up in the net by pulling a purse line to close the net, much like a purse is closed by a drawstring.)*
5. Each group gets one sweep of their net in the container (“ocean”) to catch fish. Then they sort through their catch, noting the number of each species caught. They record their catch results on the Fisheries Catch Record Worksheet. Ask each group to drag their nets two more times through the ocean, recording the results. Then they should answer the questions on the Fisheries Catch Record worksheet.
6. Ask students to discuss their catch statistics and their worksheet question answers in their groups. Create a class chart for students to review and then share ideas with the whole class. Focus question: “What claims can we make from this data, especially focusing of marine species and their ecosystems?” Explain to students that most bycatch dies even if it’s thrown back.
7. Explain that fishermen are supposed to report their catches to the NOAA Fisheries Service to help fisheries managers keep track of fish populations and therefore ensure their sustainability. Data from fishermen is one of many tools used to monitor fisheries. “What would happen if only one or two groups reported their catches to NOAA and the others did not? How does incomplete data affect sustainability efforts?”
8. Homework: Written reflection/blog post: “Based on what we know so far, how do you think bycatch affects marine ecosystems? Provide evidence to support your claim.” Comment on the posts of at least two classmates.

**DAY 4 – Bycatch Reduction Devices**

1. Explain that scientists, engineers and the fishing industry are working together to find ways to decrease bycatch by modifying existing fishing gear to be more selective, and reducing or changing fishing conditions (different times, geographic areas, or locations within the water column). The innovative fishing gear technologies are called bycatch reduction devices (BRD)—devices that allow non-target species to escape from fishing gear and/or deter non-target species from entering the area.

One group that is at the forefront of this research, the Consortium for Wildlife Bycatch Reduction, is based at the New England Aquarium in Boston. This group recognizes that changes in fishing practices should be commercially viable, operationally practical, and use the best available science to evaluate the degree to which they will result in bycatch reduction benefits for non-target species. Equally important, even if a fishing technique is shown conclusively to reduce bycatch in a particular non-target species or population, it should not pose an increased threat to other endangered species or be unsustainable for marine biodiversity in general.

1. Have students research the following websites (and others that they might find) to learn more about what innovative steps are being taken to try to reduce bycatch. They should record the information they gather on the Bycatch Reduction Device Worksheet.

* Bycatch Reduction Device in Action, Youtube, Oregon Dept of Fish and Wildlife (2:23 minutes) <http://www.youtube.com/watch?v=gwe06aoOE9g>
* Fishing Technique Modifications, Consortium for Wildlife Bycatch Reduction, <http://www.bycatch.org/research/consortium/fishing-gear-modifications>.
* Australian Seaweek,Working Together to Reduce Bycatch,

<http://www.mesa.edu.au/seaweek2007/info_sheets/working_together.pdf>

Students can also read the *New York Times* article “Fishing Gear is Altered to Ease Collateral Costs to Marine Life” (August 22, 2012).

1. View one or more of the following videos. Focus Question: “What factors are important in the design of bycatch reduction devices?”

* New England Aquarium, *Unwanted Catch* (20 minutes)
* Oregon Department of Fish and Wildlife. “Bycatch Reduction Device (BRD) in Action.” (2:24 minutes), <http://dfw.state.or.us/images/video_gallery/bycatch_reduction_device.asp>.
* Maximising Bycatch Survival, New South Wales, Australia,(1:48 minues), <https://www.youtube.com/watch?v=opO4FwGGNNI>
* *End of the Line,* New Video Group, 2010, (1 hour, 23 minutes).

1. Homework: Written reflection/blog post: “If you were going to design a bycatch reduction device, what factors do you think would be important? Why?”

**DAYS 5 & 6 – Bycatch Reduction Device Engineering Challenge**

1. Facilitate a class discussion based on the homework focus question: “What factors are important in the design of bycatch reduction devices? Why?” Record student ideas on a chart and review the factors that students think are important in the design of bycatch reduction devices. Explain that most bycatch reduction devices rely on either:

* Physically blocking the non-target species from capture (e.g., guiding it toward an escape opening)
* Using differences in behaviors between the target species and the non-target species. For instance, some types of fish swim upward when they encounter a net, others swim downward. These behaviors can be used to design bycatch reduction devices.

1. Explain that students will be considering these factors when they design a bycatch reduction device using the Engineering Design Process to solve a specific problem. Review the steps of the Engineering Design process with students (refer to the Engineering Design Process diagram).
2. Hand out the Bycatch Reduction Device Engineering Design worksheet. In groups of 3-4, students will choose one of the following target species: Atlantic herring, Atlantic striped bass, summer flounder, haddock, Atlantic mackerel, Atlantic Pollock, Atlantic sea scallop, long-finned squid, North Atlantic swordfish, or Atlantic surfclam. (Each group will choose a different species.) They will research the target species, gathering information on fishing gear used, bycatch species, target species behavior and habitat. Then they will choose a specific type of fishing gear used to harvest the target species and a specific type of bycatch that results from use of that fishing gear. The goal is to design a bycatch reduction device to reduce bycatch of the bycatch species they have chosen (for the specific type of fishing gear).
3. As shown on the Bycatch Reduction Device Engineering Design Worksheet, students will use the Engineering Design Process to draw the design and/or make a model. In a poster and presentation (or digital story), they will need to explain the basis of their design (what criteria were considered) and how it works, show the design and/or model, and explain how they would test a prototype. The presentation will be designed for a specific audience: a group of fishermen that each group wants to convince to install/implement their device. After each presentation, students should ask questions and give feedback to the presenting group, so that they can redesign their device if necessary.
4. Some websites that may be used for student research:

* NOAA Fish Watch site (Seafood Profiles) <https://www.fishwatch.gov/profiles/all-profiles>
* Fishing and Farming Methods, Monterrey Bay Aquarium Seafood Watch, <http://www.seafoodwatch.org/ocean-issues/fishing-and-farming-methods>

1. Written reflection: What did I learn from doing this project? How did my thinking change? (Students should refer to their responses to the formative assessment at the beginning of the lesson.) How did I learn it? What additional questions do I have and how can I pursue answers to them?

**Sources for This Lesson:**

* PBS. “How to Catch a Fish” lesson. <https://www-tc.pbs.org/kqed/oceanadventures/educators/pdf/OceanAdv-Catch.pdf> .
* NOAA. “Empty Oceans Lesson Plan.” <https://nmssanctuaries.blob.core.windows.net/sanctuaries-prod/media/archive/education/teachers/pdfs/sustain_seafood_lesson2.pdf>.

Sources of Readings:

* “What is Bycatch?” Consortium for Wildlife Bycatch Reduction, [www.bycatch.org/about-bycatch](http://www.bycatch.org/about-bycatch).
* “A Net Loss: The Effects of Bycatch.” PBS, Jean-Michel Cousteau Ocean Adventures, “How to Catch a Fish” lesson, <https://www-tc.pbs.org/kqed/oceanadventures/educators/pdf/OceanAdv-Catch.pdf>

Websites and Online Videos:

* Impacts of Bycatch on Ocean Life (WGBH, <http://www.pbslearningmedia.org/resource/490d1f70-77d7-48c2-a2d4-047bd21fa44c/490d1f70-77d7-48c2-a2d4-047bd21fa44c/>
* Fishing and Farming Methods, Monterrey Bay Aquarium Seafood Watch, <http://www.seafoodwatch.org/ocean-issues/fishing-and-farming-methods>
* How We Fish Matters: Addressing the Ecological Impacts of Canadian Fishing Gear, seachoice.org, <http://www.howwefish.ca>
* NOAA FishWatch site ([www.fishwatch.gov](http://www.fishwatch.gov))
* Bycatch Reduction Device in Action, Youtube, Oregon Dept of Fish and Wildlife, <http://www.youtube.com/watch?v=gwe06aoOE9g>
* Fishing Technique Modifications, Consortium for Wildlife Bycatch Reduction, <http://www.bycatch.org/research/consortium/fishing-gear-modifications>.
* Oregon Department of Fish and Wildlife. “Bycatch Reduction Device (BRD) in Action.” <http://dfw.state.or.us/images/video_gallery/bycatch_reduction_device.asp>.
* Maximising Bycatch Survival, New South Wales, Australia, <https://www.youtube.com/watch?v=opO4FwGGNNI>

Commercial Videos:

* *End of the Line,* New Video Group, 2010.<http://endoftheline.com/> or <http://www.nationalgeographic.com/endoftheline/>
* New England Aquarium, *Unwanted Catch.* For a free copy of this video, contact the Teacher Resource Center, [trc@neaq.org](mailto:trc@neaq.org), 617-973-6590.

# Lesson 9: Human Impacts on the Ocean – Overfishing

**Brief Overview of Lesson:** Students participate in a hands-on activity that simulates overfishing and illustrates the effects of overfishing fish populations. After brainstorming ways that overfishing may be reduced/prevented, students research marine species that are overfished in New England. Next, students explore the question: “How do we know how many fish there are in the sea?” via a hands-on activity focusing on fish tagging and using statistics to estimate simulated fish populations. This leads to an in-depth study of a real-world dilemma currently facing New England: overfishing of cod. Students learn about the history of cod fishing in New England (including recent actions that were taken based on inaccurate sampling data) and research the ecology of cod. Students then participate in a simulated roundtable discussion about what should be done to bring the cod populations back to sustainable levels. In groups, students are assigned the roles of different stakeholders, and research possible solutions to the problem. During the roundtable, ideas are shared, and an attempt is made to come to consensus.

**Prior Knowledge Required:** Understanding of topics investigated in Lessons 1-8

**Estimated Time:** Five 50-minute classes

**Standard(s)/Unit Goal(s) to be Addressed in This Lesson:**

* **HS-LS2-6** Analyze data to show ecosystems tend to maintain relatively consistent numbers and types of organisms even when small changes in conditions occur but that extreme fluctuations in conditions may result in a new ecosystem. Construct an argument supported by evidence that ecosystems with greater biodiversity tend to have greater resistance to change and resilience. Clarification Statement: Examples of changes in ecosystem conditions could include modest biological or physical changes, such as moderate hunting or a seasonal flood; and extreme changes, such as volcanic eruption, fires, the decline or loss of a keystone species, climate changes, ocean acidification, or sea level rise.
* **HS-LS2-7** Analyze direct and indirect effects of human activities on biodiversity and ecosystem health, specifically habitat fragmentation, introduction of non-native or invasive species, overharvesting, pollution, and climate change. Evaluate and refine a solution for reducing the impacts of human activities on biodiversity and ecosystem health. \* Clarification Statement: Examples of solutions can include captive breeding programs, habitat restoration, pollution mitigation, energy conservation, and ecotourism.
* **HS-ESS3-3** Illustrate relationships among management of natural resources, the sustainability of human populations, and biodiversity. Clarification Statements: Examples of factors related to the management of natural resources include costs of resource extraction and waste management, per capita consumption, and the development of new technologies. Examples of factors related to human sustainability include agricultural efficiency, levels of conservation, and urban planning. Examples of factors related to biodiversity include habitat use and fragmentation, and land and resource conservation.
* **HS-ETS1-3** Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, aesthetics, and maintenance as well as social, cultural, and environmental impacts.

**Big Ideas:**

* Overfishing is significantly impacting marine species and biodiversity in the ocean system.
* Fish population sampling methods have sources of error, which can drastically affect policy actions.
* The history of cod fishing in New England, which has had a great impact on New England communities, has changed significantly over time
* Scientists, agencies, the fishing industry and interest groups need to work together to find solutions to the overfishing problems in New England.

**Essential Question(s) Addressed in This Lesson:**

* How do humans impact the ocean system?
* How can ocean resources be managed to reduce human impact, make use of ocean resources by humans sustainable and maintain the diversity of the ocean system?
  + Are the ocean’s resources limitless?
  + What are the impacts of overfishing on marine species and the ocean ecosystem?
  + How do we know how many fish there are in the ocean? What sources of error are associated with sampling methods?
  + How can scientists, agencies, the fishing industry and interest groups work together to effectively manage ocean resources?

**Objectives:**

**Students will be able to…**

* Explain, using evidence, relationships among management of natural resources, the sustainability of human populations, and biodiversity in the context of overfishing.
* Analyze direct and indirect effects of human activities on biodiversity and ecosystem health.
* Gather evidence to support the claim that extreme fluctuations within an ecosystem may have significant effects.
* Research, create, and evaluate a solution to a complex real-world problem (the cod fishing dilemma in New England) based on prioritized criteria and trade-offs that account for a range of constraints
* Define the problem, including impacts, of overfishing on marine species and the ocean ecosystem.

**Targeted Academic Language:** overfishing, sampling, stakeholder

**Anticipated Student Preconceptions/Misconceptions:**

* Fish are abundant; it’s impossible to overfish any species.
* Humans have no permanent effect on the ocean—it will recover.

**Instructional Materials/Resources/Tools:**

* Overfishing in Action Simulation: popped popcorn, small paper cups, large paper plates, spoons, straws, watch or clock, Fishing Log
* Readings:
  + Clermont, Jason. “Overfishing: Are There Really Plenty of Other Fish in the Sea.” Massachusetts Marine Educators, *Flotsam & Jetsam* Spring 2010: 1-8, <http://ma-marine-ed.org/news-letter/quarterly-journal>.
  + “Striped Bass,” National Coalition for Marine Conservation.
  + “Striped Bass: Species Profile,” Massachusetts Division of Marine Fisheries, <http://www.mass.gov/eea/agencies/dfg/dmf/recreational-fishing/species-profiles-striped-bass.html>
  + History of Cod Fishing in New England
  + Remembering Cod
  + “Atlantic Cod: Species Profile,” Massachusetts Division of Marine Fisheries, <http://www.mass.gov/eea/agencies/dfg/dmf/recreational-fishing/atlantic-cod.html>
  + Cod Fishing Dilemma
* Overfishing in Action Activity:
  + - Two or three bags of popped, plain popcorn
    - Small paper cups (1/student)
    - Large paper plates (1/group)
    - Spoons (1/group)
    - Straws (1/student)
    - Watch or clock (for timing the activity)
    - Fishing log (1/student)
* Sampling Fish Populations Simulation: paper bags, Goldfish crackers, Goldfish pretzels, plastic cups, paper plates, Capture/Recapture Directions and Data Sheet
* Ecology of Atlantic Cod: Atlantic Cod Structure Key
* The Cod Roundtable: Cod Roundtable Rubric
* Rubrics: Argument Writing in Science Rubric (Grades 9-10), Argument Writing in Science Rubric (Grades 11-12)
* Science notebooks
* Projector/computer
* Access to internet

**Instructional Tips for Teacher:**

* Website links are provided in this lesson to access information on overfishing and other topics. These links are meant to be a starting point for student research. Students should be encouraged to search for their own sources of information on the Internet. If the links provided are no longer active, encourage students to search for similar information (using the original source as a starting place).

**Assessment**

* Formative**: “**Do you think the ocean’s resources are limitless? Explain your thinking.”
* Day 1 Homework/Blog Post: 1) What are the impacts of overfishing on the biodiversity of the ocean ecosystem? 2) What is being done to prevent or reduce overfishing?
* Day 2 Homework/Blog Post: 1) What actions were taken to bring striped bass populations back to sustainable levels? 2) Is information on habitat, growth, feeding and reproductive cycle important when making fisheries management decisions? Why or why not? 3) How do you think scientists gather data on striped bass (and other marine species) populations to determine if they are overfished or not?
* Day 3 Homework: Questions at the bottom of the Capture/Recapture Instructions and Data Sheet.
* Summative Assessment:
  + Roundtable discussion: Students will participate in a roundtable discussion about what should be done to bring cod populations back to sustainable levels.
  + Written assessment: What factors have led to the collapse of the cod fishing industry in New England? What do you think should be done to bring the cod populations back to sustainable levels (e.g., balance the relationship between fisheries management, humans dependence on fishing, and biodiversity)? Provide evidence to support your ideas.

**Lesson Details:**

**DAY 1 – Overfishing in Action**

Introduction (15 minutes)

1. Ask students to write a response to the following formative assessment probe on a blank sheet of paper: Do you think the ocean resources are limitless? Explain your answer.”(They should not put their names on the sheets.)
2. Do a “Toss and Tell” --Have students crumple up their papers and randomly toss them in the air at the same time. (The idea is for students to pick up or catch a paper without knowing who tossed it.) Ask students to share the ideas from the papers—chart the ideas.
3. Explain that they will be exploring this question in the next set of activities, which focus on overfishing. To begin, they will be doing a hands-on activity that simulates overfishing.

Overfishing in Action

Materials:

* Two or three bags of popped, plain popcorn
* Small paper cups (1/student)
* Large paper plates (1/group)
* Spoons (1/group)
* Straws (1/student)
* Watch or clock (for timing the activity)
* Fishing log (1/student)

Learning Activity (35 minutes)

1. Explain that the class will be doing a hands-on activity that simulates overfishing. The focus question is: “What are the effects of overfishing on fish populations?” Provide an overview of the activity, explaining that:

* Each student will be a “fisherman” whose livelihood depends on catching fish.
* Each piece of popcorn represents a fish.
* Each fisherman must catch at least two fish in each round to survive to the next fishing season.
* When the fishing season begins, students must hold their hands behind their backs and use the “fishing rod” (straw) to suck “fish” (pieces of popcorn) from the “ocean” (plate) and deposit them into their “boat” (cup).
* The fish remaining in the ocean after each fishing season represent the reproductive population, and one or two new fish will be added for every fish left in the ocean (plate).
* After each round, fishermen must record their catch in their Fishing Log.

1. Divide the class into groups of 3-4 students. Give each group one plate and each student one cup, one straw, and one copy of the Fishing Log. Put 30 popcorn pieces on each group’s plate. These are the fish that inhabit their fishing area or reef. Remind students that all fishermen fish at the same time and must keep their hands behind their backs and wait for a signal to start fishing.

*The First “Season”*

1. Give students 20 seconds for the first “season” of fishing. Note: You can change the time allotted for each season to get the required effect. For example, if students are not depleting their stocks fast enough, you may increase the “season” to 30 seconds or if they are depleting the stocks too fast, you can decrease the time.
2. After the first round, have each fisherman count his or her catch (fish in their cup), the total bycatch for the table (dropped before reaching the cup), and the total fish left in the ocean (plate). Have them record the data in their Fishing Log. Note: Bycatch is any fish (or other creature) that is unintentionally wasted. In the game, a “fish” that leaves the ocean but is not placed into the “boat” is considered bycatch and cannot be put back into the ocean or counted as catch.
3. In order to survive to the next fishing season, fishermen must catch at least two fish. Fishermen who did not catch the minimum amount must sit out for the following round. Add one or two new fish for every fish left on the plate, explaining that the fish reproduced in between the seasons.

*The Second “Season”*

1. Play a second round and have students record catches on the Fishing Log.

*The Third “Season”*

1. For the third round, tell students that some fishermen have decided to use other “gear types” to increase their catch. Give a spoon to one fisherman from each group (use of the spoon represents trawling).

*Subsequent “Seasons”*

1. Continue playing more rounds until one group runs out of fish. Note: If students are not depleting their stocks fast enough, you may give more fishermen spoons.
2. When one group runs out of fish, ask them what they would do in the real world if they caught all of the fish who inhabited their surrounding waters. (One option is to switch to a different profession, but another option is to move to another area to fish.)
3. Allow students to “invade” other groups when their area is depleted, but don’t tell them that they can do this beforehand. Fishermen may either go as a group or they may disperse separately to other areas.
4. Repeat fishing, recording, and replenishing fish stocks until all (or most) groups fish out their areas. The Fishing Log allows for up to six seasons.

*Optional Extensions to the Overfishing in Action Activity:*

* Have each group decide on a plan to make their fishery more sustainable.
* Conduct another six rounds (or less) of fishing, using the sustainability plans that the students developed. Because students know how to play, these rounds will go faster. Have students record their new season catches and compare them to the trend seen in the previous seasons.
* Another modification to this activity can be the introduction of different “species” (e.g. M&M’s). These species can be more valuable (although more difficult to catch) or incur a penalty if more than one is caught.

*Wrap-Up Discussion*

1. Conduct a discussion about the concept of sustainability. If any group did not completely deplete their fish population, discuss why this happened (less people fishing, etc.) Ask why sustainability might be an important goal for a community and why it might be difficult to achieve that goal.
2. Have each group of students brainstorm ways that they might have made the fisheries more sustainable. Some possible ways are catch limits (a certain number of popcorn pieces), marine protected areas (an area of the plate where fishing is not allowed), and bans against trawling (no use of spoons).

*Homework:*

* Go to the National Marine Fisheries Service, Office of Sustainable Fisheries website (<https://www.fisheries.noaa.gov/national/population-assessments/fishery-stock-status-updates> ) and find out what species are currently overfished in New England (see Stock Status Updates).
* Watch “Understanding Overfishing” on YouTube (by Asha De Vos), (4:21 minutes), <http://ed.ted.com/on/Vs2D6GfT>
* Read “Overfishing: Are There Really Plenty of Other Fish in the Sea” by Jason Clermont.
* Answer the following questions in a written response or blog post: 1) What are the impacts of overfishing on the ocean ecosystem? 2) What is being done to prevent or reduce overfishing?

If using blog posts, ask each student to respond to and comment on the blogs of two other students.

**DAY 2 – Striped Bass Success Story**

Striped Bass: A Fisheries Management Success Story

1. Discuss the homework questions.
2. Now that students have had a chance to experience the concept of overfishing, explain that you’d like to share a situation in which an overfishing problem appears to have been solved. This is a real-world scenario involving striped bass.
3. Ask students to read: 1) “Striped Bass,” National Coalition for Marine Conservation and 2) “Striped Bass Species Profile,” Massachusetts Division of Marine Fisheries.

Focus questions: “What actions were taken to bring striped bass populations back to sustainable levels?” “Is information on habitat, growth, feeding, reproductive cycle important when making fisheries management decisions? Why or why not?”

1. In small groups, ask students to discuss the readings and focus questions.
2. Homework: Write a written reflection or blog entry answering the focus questions.

**DAY 3 – How Many Fish Are in the Ocean?**

Sampling Fish Populations: How Many Fish Are in the Ocean?

1. Discuss the homework focus questions.
2. Explain to students: It was easy for us to count the number of fish in the overfishing hands-on activity because we could see them all. “How do you think scientists gather data on striped bass (and other marine species) populations to determine if they are overfished or not (and subsequently make management decisions)?” Ask students to write down what their thoughts are. Have them to turn and talk to a partner, then share in a group discussion.
3. Explain that typically only a sample of specific fish populations can be obtained. Inferences about the total populations must be made from these samples. Errors or inconsistences in gathering the data may significantly affect the accuracy of the data. However, the sampling data is often the best available information and decisions must be made based on it.
4. In this activity, students will be using the capture-recapture statistical method (commonly used by scientists) to determine the number of a specific marine species in a population. In this method, a number of animals (like cod) are captured, tagged, and then returned to their native habitat. Then, after some time has passed, a second group of cod are captured and counted—the number of tagged cod are noted. This is done multiple times. Scientists then estimate the number of cod in the entire population based on the proportion of number tagged to the total sample. (This method depends on the assumption that the population will be randomly distributed throughout the sample.)
5. Explain that students will be working in teams to sample and estimate the population of striped bass in the Gulf of Maine using the capture-recapture method. Since it’s unrealistic to actually capture fish, we’ll be using models in a simulation. Go over the materials that each group will get:

* A paper bag (the ocean)
* Goldfish crackers (striped bass)
* Goldfish pretzels (tagged striped bass)
* 1 plastic cup (the net)
* 1 paper plate (to count fish on)
* Capture/Recapture Directions and Data Sheet (one/student)

1. Each student will get a copy of the Capture/Recapture Instructions and Data Sheet. Before handing out the materials, go over the instructions (modeling with actual materials). There are four steps to the activity: 1) making a prediction, 2) collecting the data, and 3) analyzing the data, and 4) reflecting on the learning.
2. After students have completed the activity, assign the questions at the bottom of the Capture/Recapture Instructions and Data Sheet for homework. Also, have students go online and explore the Northeast Regional Cod Tagging Program website (<http://www.codresearch.org>). Explain that students will delve now into a real-world scenario about cod fishing in New England, culminating in a debate about the future of cod in the Gulf of Maine. To prepare for this next segment of the unit, have students read “History of Cod Fishing in New England” and “Remembering Cod.” Focus questions:

* How has New England’s cod fishing industry changed over time?
* What are the factors that have led to the collapse of the cod fishing industry in New England?
* How has the cod industry influenced human communities?

**DAYS 4 AND 5– Cod Fishing in New England**

Cod Fishing in New England (15 minutes)

1. Discuss the focus questions for the homework readings about cod fishing in New England.
2. Optional: Based on the information they have gathered, ask students to take notes and create a visual timeline showing important events in the history of cod fishing in New England. Encourage them to research online to find information that will make their timeline current.

[Optional Social Studies connection: Library of Congress lesson plan: “The New England Fishing Industry: Sea Changes in a Community Preparation,” <http://www.loc.gov/teachers/classroommaterials/lessons/seachanges/>]

Ecology of Atlantic Cod (35 minutes)

1. Remind students that when they learned about management decisions for striped bass, knowing the habitat, food sources, reproductive cycle, etc. of the fish was important so that logical, well-informed decisions could be made. In preparation for the cod debate, students will need to gather this information about the Atlantic cod. (Project the Atlantic Cod Structure diagram.)
2. In small groups, have students research the Atlantic cod using multiple reliable sources (including the MA Division of Marine Fisheries Atlantic Cod: Species Profile). Focus questions:

* What the physical and chemical features of the habitats where cod live? How do these features affect cod populations?
* What is the geographic distribution of the Atlantic cod?
* How often do cod reproduce?
* What do they eat? Who eats them?

Encourage students to pursue answers to any other questions that they may have about the Atlantic cod. If students don’t finish their research in class, they can complete it as homework.

The Cod Roundtable: How Can We Solve This Problem? ) Gathering information to prepare for the debate may take 1-2 classes and the debate itself should be at least 1 class.

1. Explain that students will participate in a simulated roundtable discussion with the various parties (stakeholders) involved in the cod fishery. Review the current scenario centering on the future of cod in the Gulf of Maine by reading “The Cod Fishing Dilemma”. (Go to <https://www.fishwatch.gov/profiles/atlantic-cod> for updates.) Have students discuss the article in small groups, then share out with the whole class.
2. Divide the class into five groups: local fishermen, large commercial fishing companies, environmental interest groups, fishery scientists, and the New England Fishery Management Council (governing body for fishery management in the Gulf of Maine). There will also need to be 1-2 mediators.
3. Have each group research and prepare to present their unique point of view about the future of cod in the Gulf of Maine to the New England Fishery Management Council. The mediators should develop questions for each group and will need to have a good grasp of the interests of each stakeholder group. Students will need to go online to gather the most recent information on the status of cod fishing in New England.
4. Explain that they will be examining several sides of the cod fishing dilemma with the goal of coming to consensus on what should be done to solve the problem. (Possible source of information for students: <http://www.talkingfish.org>.)

Written Individual Assessment (In-Class Assessment):

What factors have led to the collapse of the cod fishing industry in New England? What do you think should be done to bring the cod populations back to sustainable levels? Provide evidence to support your ideas and explain your reasoning.

**Sources for this Lesson:**

* “Overfishing/Sustainable Fishing Activity,” Massachusetts Marine Educators, “Flotsam & Jetsam,” Spring 2010, Vol. 38, No. 4 <http://ma-marine-ed.org/news-letter/quarterly-journal>.
* PBS Mathline, “Something Fishy,” (copy and paste link), <https://mass.pbslearningmedia.org/resource/8581be38-522c-41cd-9422-87d48b0254cd/8581be38-522c-41cd-9422-87d48b0254cd/#.Wyu-kVKWzIU>
* “Fishing for the Future,” California Academy of Sciences, <http://www.pbs.org/emptyoceans/educators/activities/docs/Activity-Fishing.pdf>.
* “Humans and Sturgeon: Great Debate,” Scutes, NOAA Fisheries Service, <https://www.greateratlantic.fisheries.noaa.gov/protected/scutes/teachers/language/debate_-_humans_and_sturgeon.pdf>

**Additional Resources:**

* Kurlansky, Mark. *The Cod’s Tale.* New York: G.P. Putnam’s Sons, 2001.
* Kurlansky, Mark. *Cod: A Biography of the Fish That Changed the World.* Penguin Books, 1998.
* Kurlansky, Mark. *World Without Fish*. New York: Workman Publishing, 2011.

**Resources:** Websites/Online videos:

* National Marine Fisheries Service, Office of Sustainable Fisheries website (<https://www.fisheries.noaa.gov/national/population-assessments/fishery-stock-status-updates> )
* “Understanding Overfishing” on YouTube (by Asha De Vos) (4:21 minutes), <http://ed.ted.com/on/Vs2D6GfT>
* Northeast Regional Cod Tagging Program website (<http://www.codresearch.org>).

# Lesson 10: Sustainable Seafood – Vote With Your Fork!

**Brief Overview of Lesson:** The focus of this lesson is on steps that the public can take to help increase the sustainability of fish populations. Initially, students create a concept map showing what they know about the seafood they eat. They are then introduced to the concepts of “sustainability” and “sustainable seafood” by researching information on NOAA’s FishWatch website and watching online videos. After a class discussion, each student researches an overfished species from New England, creates a fact sheet, and presents the information to the class. Next, students work in groups to design a research project to gather information on the types of seafood that are sold in their community and how they are caught. The data will be represented in charts and graphs for presentation to the class along with the group’s interpretation of what the data implies. Following a science talk comparing the data, students write letters to area businesses that sell seafood presenting what they have learned and suggested actions that the businesses might take to help promote sustainability.

**Prior Knowledge Required:** Understanding of bycatch and overfishing issues (Lessons 8 and 9)

**Estimated Time:** Six 50-minute classes

**Standard(s)/Unit Goal(s) to be Addressed in This Lesson:**

* **HS-LS2-7** Analyze direct and indirect effects of human activities on biodiversity and ecosystem health, specifically habitat fragmentation, introduction of non-native or invasive species, overharvesting, pollution, and climate change. Evaluate and refine a solution for reducing the impacts of human activities on biodiversity and ecosystem health. Clarification Statement: Examples of solutions can include captive breeding programs, habitat restoration, pollution mitigation, energy conservation, and ecotourism.
* **HS-ESS3-3** Illustrate relationships among management of natural resources, the sustainability of human populations, and biodiversity. Clarification Statements: Examples of factors related to the management of natural resources include costs of resource extraction and waste management, per capita consumption, and the development of new technologies. Examples of factors related to human sustainability include agricultural efficiency, levels of conservation, and urban planning. Examples of factors related to biodiversity include habitat use and fragmentation, and land and resource conservation.
* **HS-ETS1-3** Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, aesthetics, and maintenance as well as social, cultural, and environmental impacts.
* **W.9-10.1** Write arguments (e.g., essays, letters to the editor, advocacy speeches) to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.
* **W.11-12.1** Write arguments (e.g., essays, letters to the editor, advocacy speeches) to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.

**Big Ideas:**

* The ocean sustains life on Earth and humans must live in ways that sustain the ocean.
* Individual and collective actions are needed to effectively manage ocean resources for all.

**Essential Question Addressed in This Lesson:**

* How do Humans impact the ocean system?
* How can ocean resources be managed to reduce human impact, make the use of ocean resources by humans sustainable and maintain the diversity of the ocean system?
  + How can we become informed consumers to promote sustainable seafood?

**Objectives:**

**Students will be able to…**

* Use evidence to explain relationships among management of fisheries, the sustainability of human populations, and biodiversity.
* Analyze direct and indirect effects of human activities on biodiversity and ecosystem health
* Evaluate a solution to the complex real-world problem of overfishing based on prioritized criteria and trade-offs that account for a range of constraints
* Explain what sustainable seafood means and give examples.
* Describe two ways that consumers can become informed about the seafood that they buy.
* Describe why it is important to buy sustainable seafood.
* Write an argument about the importance of seafood sustainability.

**Targeted Academic Language:** sustainability,sustainable seafood

**Anticipated Student Preconceptions/Misconceptions:**

* Students may not realize that some of the seafood that they eat are overfished species.

**Instructional Materials/Resources/Tools:**

* Student Worksheet: The Dish on My Fish worksheet
* Rubrics: Argument Writing in Science Rubric (Grades 9-10), Argument Writing in Science Rubric (Grades 11-12)
* Projector/computer/access to internet

**Instructional Tips for Teacher:**

* The Curriculum Embedded Performance Assessment (CEPA) should be assigned following this lesson.

**Assessment**

* Formative**:** In groups, students create concept maps showing what they think they know about the seafood they eat (“Where and how do you think these species harvested? How abundant do you think they are? What is their habitat? Do you think any of these species are overfished?”)
* Summative: Argument writing assignment: Why is seafood sustainability important? What can you do to promote seafood sustainability in your community? Back up your ideas with evidence and provide your reasoning.

**Lesson Details:**

**DAY 1 – Sustainable Seafood**

1. Review the meaning of “sustainability.” Explain to students that they’ll be learning about sustainability as it relates to the fishing industry. [*Sustainability is the ability of marine animals to continue to exist over the long term.]*
2. Explain that students have learned about the effects that the fishing industry has had on marine species (bycatch) and ways that scientists/engineers and the fishermen are working together to reduce bycatch by creating innovative bycatch reduction devices. They’ve also heard about how fish are being removed from the ocean faster than they can be replenished. Examples of overfished species include: cod, sharks, Bluefin tuna, monkfish, orange roughy and Chilean seabass. Now they’ll learn how citizens can help sustain seafood populations.
3. In groups of 3*-*4, ask students to brainstorm what they think they know about the seafood they eat: the names of the seafood, where and how they are caught, and any other information they know about the species (such as its abundance in the ocean). Ask each group to record their ideas on a concept map or on chart paper. Post each group’s work and do a gallery walk (students walk around looking at the charts/concept maps). Bring the class back together to share ideas.
4. Explain about sustainable seafood, including farm-raised vs. wild-caught. (See FishWatch, <http://www.fishwatch.gov/farmed_seafood/index.htm> and <http://www.fishwatch.gov/wild_seafood/index.htm>). Consumers have power to change what types of seafood are sold---“vote with their fork.”
5. View the following videos:

* “Can the Oceans Keep Up with the Hunt?”, Monterey Bay Aquarium Seafood Watch (15 minutes), <https://ed.ted.com/on/8hq5SaLG%20>
* “Local Ocean: Meet Laura Anderson, Owner of local Ocean Seafoods.” NOAA, (3:39 minutes) <https://www.youtube.com/watch?v=LnzdXLhoVMo>
* “Boat to Belly Sneak Peek,” One World/One Ocean (2:55 minutes), <http://www.oneworldoneocean.com/video/entry/boat-to-belly-sneak-peek>

Note: If there is not enough time in class to watch all the videos, they can be assigned as homework.

1. Facilitate a class discussion on what seafood sustainability means. *[Seafood sustainability means catching or farming seafood responsibly with consideration for the long-term health of the environment and the livelihoods of fishermen.]*
2. Homework: Have students go to the NOAA FishWatch Choosing Sustainable website (<https://www.fishwatch.gov/sustainable-seafood/faqs> )to learn about sustainability. They should take notes on what they learn. Focus question: How can consumers know that seafood they are buying is sustainable?

**DAY 2 – The Dish on My (Overfished) Fish**

1. Explain that each student will be doing research on an overfished species from New England. (For current information on overfished species, visit the NOAA Office of Sustainable Fisheries quarterly stock status maps, <https://www.fisheries.noaa.gov/national/population-assessments/fishery-stock-status-updates> ) Students will learn as much as possible about the species and will record their research on The Dish on My Fish worksheet. (The Seafood Profiles on FishWatch, <https://www.fishwatch.gov/profiles/all-profiles> are a good source of information.) They will then create a fact sheet about their species and will post it online. Students will be required to read each other’s posts and comment on at least two. Optional: The fact sheets can be compiled to form a Sustainable Seafood Guide that can be distributed throughout the school and to parents.

**DAYS 3, 4 and 5 – Community Seafood Research Project**

(Suggestions: 20-30 minutes to explain the project, one in-class work session, with the remainder of the group work completed out of class, one class for the group discussion)

1. Divide the class into small groups (2-4/group). Each group will design a research project to answer the following questions:

* Where are fish sold in your community (i.e., grocery stores, fish markets, restaurants)?
* What are the five most popular types of fish sold at each place?
* Which of these species are facing overfishing pressures? (See the NOAA Office of Sustainable Fisheries quarterly stock status maps to get this information, <https://www.fisheries.noaa.gov/national/population-assessments/fishery-stock-status-updates> )
* Which of these species are sustainable seafood?
* Where does each type of seafood come from (i.e., country of origin, part of the ocean)?
* Are the species wild-caught or farm-raised?
* How is the seafood caught?
* What is the price at each location?

1. Tell students that they will represent this data in graphs and charts to present to the class. Each group should interpret the data and explain the implications of the amount and type of seafood consumed in the community and on the sustainability of the species. (Students can be given the opportunity to plan their project in class and then work on it out of class.)
2. Synthesize the information presented in a group discussion comparing the data and the groups’ ideas about implications on the sustainability of seafood species.
3. Optional: Have students write letters to an area business that sells seafood, presenting what they have learned and outlining actions that they would like to see the business take to help promote sustainability. Alternatively, students could put together a consumer’s guide to buying local seafood.

**DAY 6 – Wrap-Up & Reflection**

1. Facilitate a science talk about what individuals can do to make wise choices about sustainable seafood. (Remind students that they have a choice when buying seafood and they can make smart choices.) Compile a list of student ideas. Some talking points to include:

* Consumers should stay informed and make sure they are using the most up-to-date, credible sources.
* Seafood should be bought from knowledgeable, reputable dealers who purchase seafood from sustainable sources.
* Consumers should ask questions about seafood. Where is it from? Is it wild-caught or farm-raised? How fresh is it?

1. Written Summative Assessment: Why is seafood sustainability important? What can you do to promote seafood sustainability in your community? Back up your ideas with evidence.
2. Reflection: What have I learned during this unit? What questions do I still have that I’d like to learn more about?

**Sources of This Lesson:**

* PBS. “How to Catch a Fish” lesson. <https://mass.pbslearningmedia.org/resource/pbs_org14_jmcoa_sci_25/jean-michel-cousteau-ocean-adventures-lesson-plan-how-to-catch-a-fish/#.Wyu-P1KWzIU>
* NOAA. “Empty Oceans Lesson Plan.” <https://nmssanctuaries.blob.core.windows.net/sanctuaries-prod/media/archive/education/teachers/pdfs/sustain_seafood_lesson2.pdf>.

# Curriculum Embedded Performance Assessment (CEPA)

**Take Action to Protect the Gulf of Maine Ocean System!**

**Brief Overview:** In this unit, students have learned about the parts of the Gulf of Maine ocean system and how the geology, physical features of ocean water, and living things all depend on each other. They also became aware of the human impact on this system via bycatch and overfishing. As they now know, the Gulf of Maine is in a fragile state. However, there are things that we can do to help.

As a culminating assessment, students will work in groups to create a digital story, presentation, or other mode of communication outlining what they have learned about the Gulf of Maine ocean system designed to share with middle school students.

The main goals of the project are to: 1) synthesize what they have learned in a clear and concise fashion, 2) communicate how important it is to take steps to save our valuable ocean system resources, and 3) empower the audience (middle school students) to take action in their community.

**Estimated Time:** Two to three 50-minute sessions

**Materials:**

* Maps and other resource materials used in the unit
* Other materials needed (depending on the type of presentation students choose), such as laptops, a projector, chart paper, markers, etc.
* CEPA Rubric

**Standards to be Assessed:**

* **HS-LS2-2** Use mathematical representations to support explanations that biotic and abiotic factors affect biodiversity, including genetic diversity within a population and species diversity within an ecosystem. Clarification Statements: Examples of biotic factors could include relationships among individuals (feeding relationships, symbiosis, competition) and disease. Examples of abiotic factors could include climate and weather conditions, natural disasters, and availability of resources. Examples of mathematical representations include finding the average, determining trends, and using graphical comparisons of multiple sets of data.
* **HS-LS2-6** Analyze data to show ecosystems tend to maintain relatively consistent numbers and types of organisms even when small changes in conditions occur but that extreme fluctuations in conditions may result in a new ecosystem. Construct an argument supported by evidence that ecosystems with greater biodiversity tend to have greater resistance to change and resilience. Clarification Statement: Examples of changes in ecosystem conditions could include modest biological or physical changes, such as moderate hunting or a seasonal flood; and extreme changes, such as volcanic eruption, fires, the decline or loss of a keystone species, climate changes, ocean acidification, or sea level rise.
* **HS-LS2-7** Analyze direct and indirect effects of human activities on biodiversity and ecosystem health, specifically habitat fragmentation, introduction of non-native or invasive species, overharvesting, pollution, and climate change. Evaluate and refine a solution for reducing the impacts of human activities on biodiversity and ecosystem health. \* Clarification Statement: Examples of solutions can include captive breeding programs, habitat restoration, pollution mitigation, energy conservation, and ecotourism.
* **HS-ESS3-3** Illustrate relationships among management of natural resources, the sustainability of human populations, and biodiversity. Clarification Statements: Examples of factors related to the management of natural resources include costs of resource extraction and waste management, per capita consumption, and the development of new technologies. Examples of factors related to human sustainability include agricultural efficiency, levels of conservation, and urban planning. Examples of factors related to biodiversity include habitat use and fragmentation, and land and resource conservation.

**Overview of CEPA:**

**Goal:** Synthesize what you have learned about the Gulf of Maine and clearly communicate (visually and orally) this summary with others. Communicate how important it is to take steps to save our valuable ocean system resources and empower middle school students to take action in their community.

**Role:** Scientist

**Audience:** Middle school students

**Situation:** You have been hired to share information about the geology, physical features, and biology of the Gulf of Maine with the public in order to build awareness and increase protection of the Gulf of Maine’s marine resources.

**Product:** A digital story, presentation, or other mode of communication outlining what you have learned about the Gulf of Maine ocean system designed to share with middle school students.

**Assessment Activities** (Suggestions: 30 minutes for student reflection, 15 minutes for explanation of the assessment, one to two 50-minute sessions for students to work on the assessment, in addition to out of class time):

**Teacher Directions:**

1. Ask students to reflect on what they learned in this unit and how they have learned it. (It may help for them to review their science notebooks or other resources to jog their memories.) Using this information, revise/add to the Gulf of Maine concept maps that they created in the first lesson. How has their thinking changed since then? (30 minutes)
2. Explain that they are going to get a chance to share what they learned with middle school students by creating a digital story, presentation or other mode of communication. The scenario is that they are scientists who have been hired to share information about the geology, physical features, and biology of the Gulf of Maine with the public in order to build awareness and increase protection of the Gulf of Maine’s marine resources. The goal is to communicate (clearly and concisely) how important it is to take steps to save our valuable ocean system resources and empower the audience (middle school students) to take action in their community.
3. The presentation must include information about the following that is communicated clearly visually and orally:

* Factors explaining why the Gulf of Maine is one of the most biodiverse and productive marine areas in the world (including the effect of geology and the characteristics of ocean water on marine species)
* The Gulf of Maine ecosystem, including the interaction of living and nonliving things
* The Stellwagen Bank National Marine Sanctuary and its role in preserving ocean resources
* Issues that face marine species and the environment in the Gulf of Maine (bycatch, overfishing, marine debris, etc.)
* Steps that consumers can take to help marine species become sustainable

1. Share the rubric with students and explain it in detail. Be sure that they are all clear on what the expectations are.

**Student Directions:**

You are scientists who have been hired to share information about the geology, physical features, and biology of the Gulf of Maine with the public (specifically middle school students) in order to build awareness and increase protection of the Gulf of Maine’s marine resources. Your goal is to clearly and concisely communicate how important it is to take steps to save our valuable ocean system resources and empower the middle school students to take action in their community.

Your team’s presentation (which can be a digital story, Prezi, or other type of presentation) must include information about:

* Factors explaining why the Gulf of Maine is one of the most biodiverse and productive marine areas in the world (including the effect of geology and the characteristics of ocean water on marine species)
* The Gulf of Maine ecosystem, including the interaction of living and nonliving things
* The Stellwagen Bank National Marine Sanctuary and its role in preserving ocean resources
* Issues that face marine species and the environment in the Gulf of Maine (bycatch, overfishing, marine debris, etc.)
* Steps that consumers can take to help marine species become sustainable

Be sure to use the rubric as a guide to make sure you meet all the expectations.

**Curriculum Embedded Performance Assessment (CEPA) Rubric**

**Take Action to Protect the Gulf of Maine Ocean System!**

Presentation Content Requirements:

* Why the Gulf of Maine is one of the most biodiverse and productive marine areas in the world (including the effect of geology and the characteristics of ocean water on marine species)
* The Gulf of Maine ecosystem, including the interaction of living and nonliving things
* The Stellwagen Bank National Marine Sanctuary and its role in preserving ocean resources
* Issues that face marine species and the environment in the Gulf of Maine (bycatch, overfishing, marine debris)
* Steps that consumers can take to help marine species become sustainable

| **Description** | **Novice** | **Developing** | **Proficient** | **Advanced** |
| --- | --- | --- | --- | --- |
| ***Science Content***  Demonstrates understanding of the Gulf of Maine ocean system | Demonstrates only a few of the presentation content requirements  Does not use scientific vocabulary appropriately or accurately | Demonstrates a deep understanding of most of the presentation content requirements  Uses scientific vocabulary appropriately and accurately in some places | Demonstrates a deep understanding of all of the presentation content requirements  Uses scientific vocabulary appropriately and accurately (explaining the meaning for the audience when necessary) | Demonstrates a deep understanding of all of the presentation content requirements and topics that go beyond grade level expectations  Uses advanced scientific vocabulary appropriately and accurately |
| ***Presentation of Knowledge and Ideas***  Communicate information in a clear, concise way and empower the audience (middle school students) to take action in their community | The purpose is not stated  Does not present information, findings, arguments clearly, concisely and logically; the audience cannot follow the line of reasoning  Argument lacks supporting evidence  No digital media are used  No enthusiasm or interest for the topic is exhibited  Only one member of the group speaks | States the purpose, but it is vague or unclear  Presents information, findings, arguments and supporting evidence in a way that is not always clear, concise and logical; the line of reasoning if sometimes hard to follow  Uses digital media, but it does not enhance the presentation or add interest  Enthusiasm and interest for the topic is modeled rarely throughout the presentation  Only a few members of the group take turns speaking | Clearly states the purpose  Presents information, findings, arguments and supporting evidence clearly, concisely, and logically so the audience can follow the line of reasoning  Makes strategic use of digital media to enhance the presentation and to add interest  Models enthusiasm and interest for the topic  Members of the group take turns speaking | Clearly states the purpose  Skillfully presents information, findings, arguments and supporting evidence clearly, concisely, and logically so the audience can follow the line of reasoning  Makes strategic and skillful use of digital media to enhance the presentation and to add interest  Models enthusiasm and interest for the topic and sparks this enthusiasm in the audience  Members of the group take turns speaking; transitions between speakers are smooth and seamless |
| ***Organization, Development & Style***  Organize the information in a clear, understandable and engaging way | The organization, development, substance and style are not appropriate to purpose, audience and the task  No introduction and/or conclusion are provided | The organization, development, substance and style are partially appropriate to purpose, audience and the task  Has an introduction and conclusion, but they are not clear or interesting | The organization, development, substance and style are appropriate to purpose, audience and the task  Has a clear, interesting introduction that states the purpose and a conclusion that summarizes the main idea | The organization, development, substance and style are skillfully targeted to be appropriate to purpose, audience and the task  Has a clear, interesting introduction that states the purpose and a conclusion that summarizes the main idea and sparks the audience to take action |
| ***Delivery***  Effectively present the information to the audience with poise in a comfortable manner | Does not look at the audience; reads notes or slides  Lacks poise and confidence (fidgets, slouches, appears nervous)  Mumbles or speaks too quickly or slowly  Speaks too softly to be understood  Frequently uses “filler” words (“like,” um,” etc.)  Does not adapt speech for the context and task | Makes infrequent eye contact; reads notes or slides most of the time  Shows some poise and confidence (only a little fidgeting or nervous movement)  Speaks clearly most of the time  Speaks loudly enough for the audience to hear most of the time, but may speak in a monotone  Occasionally uses filler words (“like,” “um,” etc.)  Attempts to adapt speech for the context and task, but is unsuccessful or inconsistent | Keeps eye contact with the audience most of the time; only glances at note or slides  Looks poised and confident  Speaks clearly; not too quickly or slowly  Speaks loud enough for everyone to hear; changes tone and pace to maintain interest  Rarely uses filler words (“like,” “um,” etc.)  Adapts speech for the context and task to meet the needs of the audience, demonstrating a command of formal English | Keeps eye contact with the audience most of the time; does not use notes  Looks and acts poised and confident  Speaks clearly; not too quickly or slowly  Speaks loud enough for everyone to hear; changes tone and pace to maintain interest  Does not use filler words (“like,” “um,” etc.)  Adapts speech for the context and task to meet the needs of the audience, demonstrating a skillful command of formal English |

Source: Adapted from Buck Institute for Education (<http://bie.org/object/document/9_12_presentation_rubric_ccss_aligned>) and the Massachusetts English Language Arts Framework

# Unit Resources

**How to use this section:**

* All resources are listed by lesson below
* Argument Writing in Science Rubrics (Grades 9-10 & Grades 11-12) are located at the end of the Unit Resources Section.
* All other unit handouts & resources listed below are posted in a separate file on the Model Curriculum Units website(<http://www.doe.mass.edu/frameworks/mcu/>, Ocean Systems (High School) Resources)

**Lesson 1**

* Maps and diagrams:
  + The Gulf of Maine map
* Readings:
  + The Gulf of Maine reading

**Lesson 2**

* Maps and diagrams:
  + Ocean Layers Diagram-Blank
  + Structured Layering of the Ocean Diagram
  + Phytoplankton Photo
  + Seasonal Productivity in Surface Waters Diagram
* (Optional) Interactive Read Aloud: *Ocean Sunlight: How Tiny Plants Feed the Seas* by Molly Bang and Penny Chisholm, The Blue Sky Press, 2012 and the Ocean Sunlight Interactive Read Aloud Plan

**Lesson 3**

* Maps and diagrams:
  + Major Ocean Currents map
  + Uneven Heating of Earth diagram

**Lesson 4**

* Maps and diagrams:
  + Gulf of Maine map (refer to image from lesson 1)
  + Gulf of Maine Chlorophyll Satellite Images (2012 monthly composites) from the University of Maine. (One set per 2-4 students)
  + Gulf of Maine Sea Surface Temperature (SST) Satellite Images (2012 monthly composites) from the University of Maine. (One set per 2-4 students)
  + Gulf of Maine Bathymetry map (one per 2-4 students),
  + Gulf of Maine Currents map (one per 2-4 students)
* Readings: “Seasons in the Sea” by Dr. Ann Michelle Morrison (one copy per student)
* Rubrics: Argument Writing in Science Rubric (Grades 9-10), Argument Writing in Science Rubric (Grades 11-12)

**Lesson 5**

* Maps and diagrams:
  + NOAA Our National Sanctuaries map, Gerry E. Studds Stellwagen Bank National Marine Sanctuary map (map found in lesson 7 handouts)
  + Stellwagen Bank Upwellings and Slicks
  + Stellwagen Bank Food Web
* Readings:
  + NOAA National Marine Sanctuaries Frequently Asked Questions
  + “Forward” from *Stellwagen Bank* by Nathalie Ward
  + “The Pageant of Life” from *Stellwagen Bank* by Nathalie Ward
  + “Site History and Resources” from the National Marine Sanctuary Condition Report
  + “Pressures on the Sanctuary” from the National Marine Sanctuary Condition Report
  + “The Stellwagen Bank Ecosystem” from *Stellwagen Bank* by Nathalie Ward

**Lesson 6**

* Food Web Activity Resources:
  + Stellwagen Bank Food Web Worksheet
  + Stellwagen Bank Photo Cards
  + Stellwagen Bank Food Web Key (teacher reference only)
* Rubrics: Argument Writing in Science Rubric (Grades 9-10), Argument Writing in Science Rubric (Grades 11-12)

**Lesson 7**

* Maps and diagrams:
  + National Marine Sanctuary Map
* Student worksheets:
  + National Marine Sanctuary Student Project Worksheet
  + National Marine Sanctuary For Further Understanding Worksheet
* Rubrics*:* Argument Writing in Science Rubric (Grades 9-10), Argument Writing in Science Rubric (Grades 11-12)

**Lesson 8**

* Teacher Background:
  + Bycatch Teacher Background
* Readings:
  + “What is Bycatch?” (Consortium for Wildlife Bycatch Reduction)
  + “A Net Loss: The Effects of Bycatch” (PBS, Jean-Michel Cousteau Ocean Adventures)
* Student Worksheets/Handouts:
  + Types of Fishing Gear
  + Fisheries Catch Record Sheet
  + Fishing Gear Research Worksheet
  + Bycatch Reduction Device Worksheet
  + Steps of the Engineering Design Process (DESE)
  + Bycatch Reduction Device Engineering Design Worksheet

**Lesson 9**

* Readings:
  + Clermont, Jason. “Overfishing: Are There Really Plenty of Other Fish in the Sea.” Massachusetts Marine Educators, *Flotsam & Jetsam* Spring 2010: 1-8, <http://ma-marine-ed.org/news-letter/quarterly-journal>.
  + “Striped Bass,” National Coalition for Marine Conservation.
  + “Striped Bass: Species Profile,” Massachusetts Division of Marine Fisheries, <http://www.mass.gov/eea/agencies/dfg/dmf/recreational-fishing/species-profiles-striped-bass.html>
  + History of Cod Fishing in New England
  + Remembering Cod
* Images/Diagrams:
  + “Atlantic Cod: Species Profile,” Massachusetts Division of Marine Fisheries, <http://www.mass.gov/eea/agencies/dfg/dmf/recreational-fishing/atlantic-cod.html>
  + Cod Fishing Dilemma
  + Ecology of Atlantic Cod: Atlantic Cod Structure Key
* Student Worksheets:
  + Sampling Fish Populations Simulation
  + Capture/Recapture Directions and Data Sheet
* Rubrics:
  + Argument Writing in Science Rubric (Grades 9-10), Argument Writing in Science Rubric (Grades 11-12)
  + The Cod Roundtable: Cod Roundtable Rubric

**Lesson 10**

* Student Worksheet:
  + The Dish on My Fish worksheet
* Rubrics:
  + Argument Writing in Science Rubric (Grades 9-10), Argument Writing in Science Rubric (Grades 11-12)

**Argument Writing in Science Rubric (Grades 9-10)**

Based on the Massachusetts Science, Technology & Engineering Framework and English Language Arts Framework

| **Description** | **Novice** | **Developing** | **Proficient** | **Advanced** |
| --- | --- | --- | --- | --- |
| ***Claim*** *(A statement or conclusion that answers the original question/problem based on evidence)*  A clear arguable claim is made to answer a question | Does not make a claim or the claim is not relevant to the question  Does not establish the significance of the claim  Does not distinguish the claim(s) from alternate or counterclaims | Makes an incomplete or unclear claim that is relevant to the question  Attempts to, but does not clearly establish the significance of the claim  Attempts to, but does not clearly distinguish the claim(s) from alternate or counterclaims | Makes a clear, knowledgeable claim relevant to the question  Establishes the significance of the claim(s)  Distinguishes the claim(s) from alternate or counterclaims | Makes a clear, knowledgeable and insightful claim relevant to the question  Establishes the significance of the claim(s)  Clearly distinguishes the claim(s) from alternate or counterclaims |
| ***Evidence*** *(Scientific data that supports the claim)*  Relevant and sufficient evidence is provided from accurate, reliable sources to support the claim(s) and counterclaims | Does not provide evidence to support the claim or only provides evidence that is not relevant or is unreliable  Does not develop claim(s) and counterclaims fairly-the strengths and limitations of both are not addressed | Provides relevant, but insufficient evidence to support the claim(s) and counterclaims  Most of the evidence is from accurate, reliable sources  Attempts to develop claim(s) and counterclaims fairly, but does not point out the strengths and limitations of both | Provides the most relevant and sufficient evidence to support the claim(s) and counterclaims  The evidence is from accurate, reliable sources  Develops claim(s) and counterclaims fairly, pointing out the strengths and limitations of both | Provides the most relevant and sufficient evidence to support the claim(s) and counterclaims  The evidence is from accurate, reliable sources  Develops claim(s) and counterclaims fairly and thoroughly, pointing out the strengths and limitations of both  Evaluates key evidence in light of explicit criteria and other cited evidence |
| ***Reasoning*** *(the big scientific idea or principle that connects the claim and evidence)*  Logical reasoning is provided to link the claim and the evidence | Does not provide logical reasoning to connect the claim and evidence, or provides inappropriate reasoning | Provides weak reasoning to link the claim and evidence | Provides strong, logical reasoning to link the claim and evidence | Provides strong, logical reasoning to link the claim and evidence  The reasoning demonstrates understanding that is beyond grade level expectations |
| ***Organization***  The argument is logically organized | The claim is not introduced at the beginning of the argument  The argument is unorganized and clear relationships among claim(s), counterclaims, reasons and evidence are not established | The claim is introduced at the beginning of the argument  The argument is not clearly organized in a way that establishes relationships among claim(s), counterclaims, reasons and evidence | The claim is introduced at the beginning of the argument  The argument is organized in a way that establishes clear relationships among claim(s), counterclaims, reasons and evidence | The claim is introduced at the beginning of the argument  The argument is organized in a way that logically sequences claim(s), counterclaims, reasons and evidence |
| ***Audience***  The writer anticipates the knowledge level and concerns of the audience | Does not anticipate the audience’s knowledge level and concerns | Attempts to anticipate the audience’s knowledge level and concerns, but not all of these factors are considered | Anticipates the audience’s knowledge level and concerns | Anticipates the audience’s knowledge level, concerns, values, and possible biases and skillfully tailors the argument using this knowledge |
| ***Cohesion***  The writer connects the text in a cohesive manner and clarifies components of the argument | Does not use words, phrases, and clauses to link the major sections of the text  The argument is not cohesive  The relationships between claim(s) and reasons, between reasons and evidence, and between claim(s) and counterclaims are not clarified | Uses words, phrases, and clauses to link the major sections of the text some of the time  Attempts to create cohesion, but the argument is disjointed at times  The relationships between claim(s) and reasons, between reasons and evidence, and between claim(s) and counterclaims are not clarified | Uses words, phrases, and clauses to link the major sections of the text, create cohesion, and clarify the relationships between claim(s) and reasons, between reasons and evidence, and between claim(s) and counterclaims | Uses words, phrases, and clauses as well as varied syntax to skillfully link the major sections of the text, create cohesion, and clarify the relationships between claim(s) and reasons, between reasons and evidence, and between claim(s) and counterclaims |
| ***Style and Tone***  The writer uses a formal style and objective tone | Does not establish and maintain a formal style and objective tone  Does not attend to the norms and conventions of the discipline | Establishes and maintains a formal style and objective tone throughout some of the argument  Attempts to attend to the norms and conventions of the discipline | Establishes and maintains a formal style and objective tone while attending to the norms and conventions of the discipline | Establishes and maintains a formal style and objective tone while attending to the norms and conventions of the discipline. Effectively uses rhetorical devices (such as metaphor, analogy, etc.) |
| ***Conclusion***  A conclusion is provided that supports the argument | Does not provide a concluding statement or section that follows from and supports the argument presented, or the concluding statement or section does not follow from or support the argument presented | Provides a weak concluding statement or section that partly follows from and supports the argument presented | Provides a concluding statement or section that follows from and supports the argument presented | Provides a concluding statement or section that follows from and supports the argument presented. Articulates implications and significance of the claim in terms of both the world and related evidence. |
| ***Science Content and Vocabulary***  The writer demonstrates an understanding of the topic and uses scientific vocabulary appropriately | Does not demonstrate an understanding of the topic and does not use scientific vocabulary appropriately or accurately in the argument | Demonstrates a fairly accurate understanding of the topic and use scientific vocabulary appropriately and accurately in some places in the argument | Demonstrates a deep understanding of the topic and use scientific vocabulary appropriately and accurately throughout the argument | Demonstrates a deep, sophisticated understanding of the topic and use advanced scientific vocabulary appropriately and accurately throughout the argument |

Source: Janet MacNeil, <http://the-curious-scientist.weebly.com/curriculum.html>

**Argument Writing in Science Rubric (Grades 11-12)**

Based on the Massachusetts Science, Technology & Engineering Framework and English Language Arts Framework

| **Description** | **Novice** | **Developing** | **Proficient** | **Advanced** |
| --- | --- | --- | --- | --- |
| ***Claim*** *(A statement or conclusion that answers the original question/problem based on evidence)*  A clear arguable claim is made to answer a question | Does not make a claim or the claim is not relevant to the question  Does not establish the significance of the claim  Does not distinguish the claim(s) from alternate or counterclaims | Makes an incomplete or unclear claim that is relevant to the question  Attempts to, but does not clearly establish the significance of the claim  Attempts to, but does not clearly distinguish the claim(s) from alternate or counterclaims | Makes a clear, knowledgeable claim relevant to the question  Establishes the significance of the claim(s)  Distinguishes the claim(s) from alternate or counterclaims | Makes a clear, knowledgeable and insightful claim relevant to the question  Establishes the significance of the claim(s)  Clearly distinguishes the claim(s) from alternate or counterclaims |
| ***Evidence*** *(Scientific data that supports the claim)*  Relevant and sufficient evidence is provided from accurate, reliable sources to support the claim(s) and counterclaims | Does not provide evidence to support the claim or only provides evidence that is not relevant or is unreliable  Does not develop claim(s) and counterclaims fairly and thoroughly-the strengths and limitations of both are not addressed | Provides relevant, but insufficient evidence to support the claim(s) and counterclaims  Most of the evidence is from accurate, reliable sources  Attempts to develop claim(s) and counterclaims fairly and thoroughly, but does not point out the strengths and limitations of both | Provides the most relevant and sufficient evidence to support the claim(s) and counterclaims  The evidence is from accurate, reliable sources  Develops claim(s) and counterclaims fairly and thoroughly, pointing out the strengths and limitations of both | Provides the most relevant and sufficient evidence to support the claim(s) and counterclaims  The evidence is from accurate, reliable sources  Develops claim(s) and counterclaims fairly and thoroughly, pointing out the strengths and limitations of both  Evaluates key evidence in light of explicit criteria and other cited evidence |
| ***Reasoning*** *(the big scientific idea or principle that connects the claim and evidence)*  Logical reasoning is provided to link the claim and the evidence | Does not provide logical reasoning to connect the claim and evidence, or provides inappropriate reasoning | Provides weak reasoning to link the claim and evidence | Provides strong, logical reasoning to link the claim and evidence | Provides strong, logical reasoning to link the claim and evidence  The reasoning demonstrates understanding that is beyond grade level expectations |
| ***Organization***  The argument is logically organized | The claim is not introduced at the beginning of the argument  The argument is unorganized and there is no logical sequence of the claim(s), counterclaims, reasons and evidence | The claim is introduced at the beginning of the argument  The argument is not clearly organized in a way that logically sequences claim(s), counterclaims, reasons and evidence | The claim is introduced at the beginning of the argument  The argument is organized in a way that logically sequences claim(s), counterclaims, reasons and evidence | The claim is introduced at the beginning of the argument  The argument is skillfully organized in a way that logically sequences claim(s), counterclaims, reasons and evidence |
| ***Audience***  The writer anticipates the nature and needs of the audience | Does not anticipate the audience’s knowledge level, concerns, values, and possible biases | Attempts to anticipate the audience’s knowledge level, concerns, values, and possible biases, but not all of these factors are considered | Anticipates the audience’s knowledge level, concerns, values, and possible biases | Anticipates the audience’s knowledge level, concerns, values, and possible biases and skillfully tailors the argument using this knowledge |
| ***Cohesion***  The writer connects the text in a cohesive manner and clarifies components of the argument | Does not use words, phrases, and clauses to link the major sections of the text  The argument is not cohesive  The relationships between claim(s) and reasons, between reasons and evidence, and between claim(s) and counterclaims are not clarified | Uses words, phrases, and clauses to link the major sections of the text some of the time  Attempts to create cohesion, but the argument is disjointed at times  The relationships between claim(s) and reasons, between reasons and evidence, and between claim(s) and counterclaims are not clarified | Uses words, phrases, and clauses as well as varied syntax to link the major sections of the text, create cohesion, and clarify the relationships between claim(s) and reasons, between reasons and evidence, and between claim(s) and counterclaims | Uses words, phrases, and clauses as well as effective varied syntax to skillfully link the major sections of the text, create cohesion, and clarify the relationships between claim(s) and reasons, between reasons and evidence, and between claim(s) and counterclaims |
| ***Style and Tone***  The writer uses a formal style and objective tone | Does not establish and maintain a formal style and objective tone  Does not attend to the norms and conventions of the discipline | Establishes and maintains a formal style and objective tone throughout some of the argument  Attempts to attend to the norms and conventions of the discipline | Establishes and maintains a formal style and objective tone while attending to the norms and conventions of the discipline | Establishes and maintains a formal style and objective tone while attending to the norms and conventions of the discipline. Effectively uses rhetorical devices (such as metaphor, analogy, etc.) |
| ***Conclusion***  A conclusion is provided that supports the argument | Does not provide a concluding statement or section that follows from and supports the argument presented, or the concluding statement or section does not follow from or support the argument presented | Provides a weak concluding statement or section that partly follows from and supports the argument presented | Provides a concluding statement or section that follows from and supports the argument presented | Provides a concluding statement or section that follows from and supports the argument presented. Articulates implications and significance of the claim in terms of both the world and related evidence. |
| ***Science Content and Vocabulary***  The writer demonstrates an understanding of the topic and uses scientific vocabulary appropriately | Does not demonstrate an understanding of the topic and does not use scientific vocabulary appropriately or accurately in the argument | Demonstrates a fairly accurate understanding of the topic and use scientific vocabulary appropriately and accurately in some places in the argument | Demonstrates a deep understanding of the topic and use scientific vocabulary appropriately and accurately throughout the argument | Demonstrates a deep, sophisticated understanding of the topic and use advanced scientific vocabulary appropriately and accurately throughout the argument |

Source: Janet MacNeil, <http://the-curious-scientist.weebly.com/curriculum.html>