A Climate of Change Part IV: The Future of Aquaculture

Educator's Guide for Middle and High School Students

ISLAND INSTITUTE

September 2016

Introduction

A Climate of Change: The Future of Aquaculture is a short documentary focused on the increasing interest in aquaculture along the coast of Maine as a complement to traditional lobstering, clamming and other types of fishing. More and more resource harvesters see farming shellfish and sea vegetables as a viable and sustainable way to continue working on the water. With Maine's fisheries facing an uncertain future, marine-related economic diversification can help support Maine's island and remote coastal communities. Shellfish and seaweed aquaculture can provide fishermen and their families a way to continue the tradition of making a living on the water for years to come.

The Educator's Guide for *A Climate of Change: The Future of Aquaculture* is designed to help middle and high school teachers bridge different ideas between the science and social aspects of aquaculture. Teachers should view the documentary to be familiar with the stories and science concepts highlighted throughout the film. The guide is divided into two sections: 1) the natural environment and ecosystems, and 2) the human dimension in the ecosystem. Within each section there are corresponding lesson plans and activities for teachers to consider using in their classrooms. *A Climate of Change: The Future of Aquaculture* can fit into many subject areas and we look forward to hearing how you have used this documentary in your classroom. **If you have questions or feedback, please email Yvonne Thomas, Education Director at the Island Institute, at ythomas@islandinstitute.org or fill out this survey: https://www.surveymonkey.com/r/S9GJXPY**

The film is accessible at http://www.islandinstitute.org/media/climate-change-pt-4

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Acknowledgments

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Climate of Change Part IV: The Future of Aquaculture

Lesson Plan

Oceanography 101

Essential Questions

- What are the components of oceanography?
- What are the major currents in the Gulf of Maine?
- How do the currents of the Gulf of Maine affect our environment?

Overview

Oceanography is a broad field focused on the interconnections between geology, geography, geophysics, physics, chemistry, geochemistry, mathematics, meteorology, botany, and zoology. Because the field is so large, it has been broken down into a number of sub-disciplines. Through this lesson, students will gain a better understanding of the physical structure of the Gulf of Maine (GoM) including the unique semi-enclosed shape of the Gulf, freshwater input, currents, tidal action, and water temperature.

The final product of this lesson will be a diagram modeling the many elements that make the GoM unique. These diagram will be used to help with classroom discussions around the changes seen in the GoM and how these changes may affect the daily lives of those who rely on a healthy ocean for their livelihoods.

Objectives

- Students will explain the physical structure of the GoM and the direction and causes of GoM currents.
- Students will observe and monitor water temperature and other parameters from buoys in the GoM.

Standards

Next Gen Science Standards:

- HS-ESS2-5. Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.
- MS-ESS2-5. Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions.

Duration

60 Minutes

Subjects

- Science
- Geography
- Math
- English Language Arts

Materials

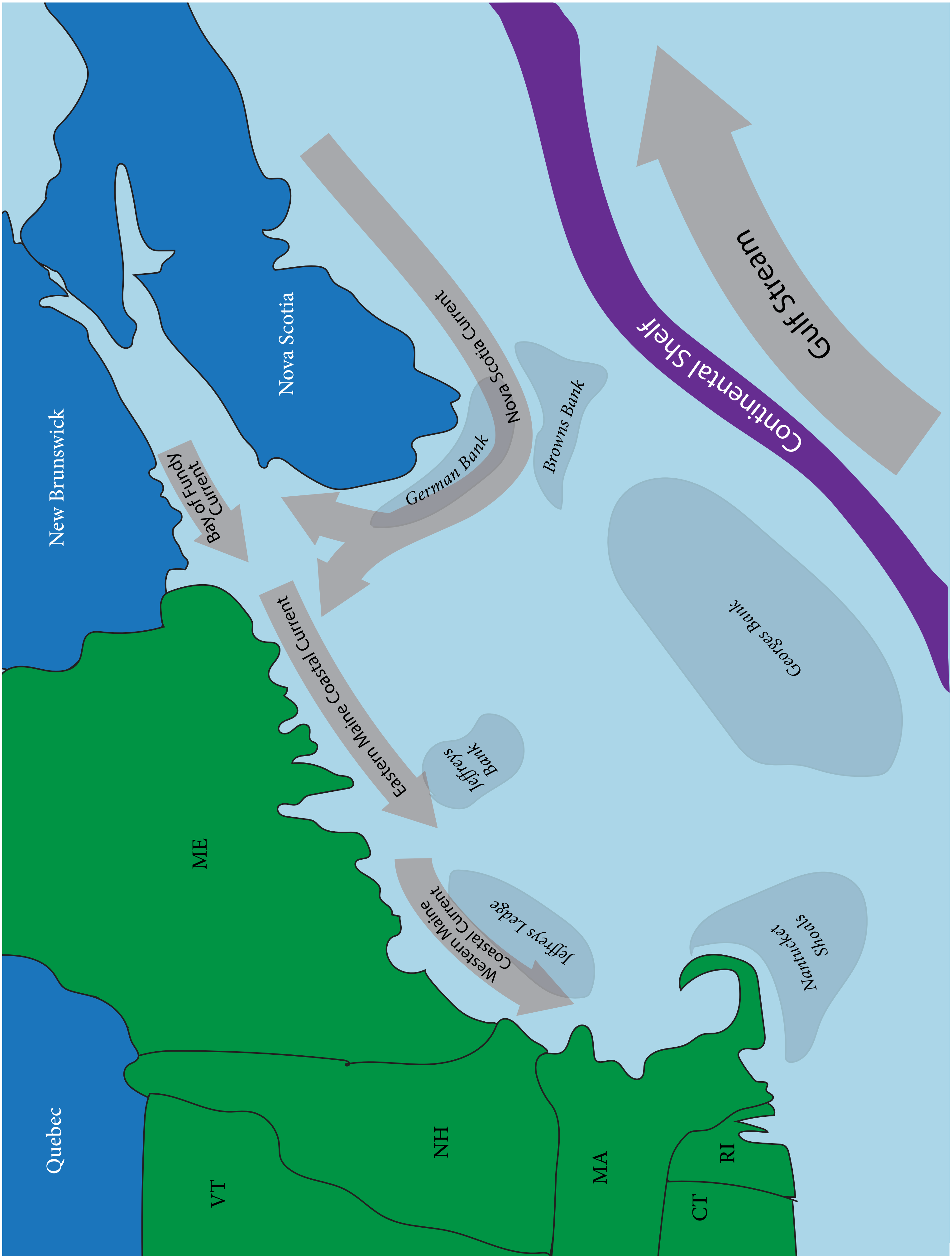
- At least five different colors of felt (full sheet of one color for background)
- GoM felt template (included here)
- GoM felt pieces for each student group (teachers may cut out before the start of the lesson)
- Foam boards for felt
- Adhesive/glue
- Laptop
- Small post-notes for labels

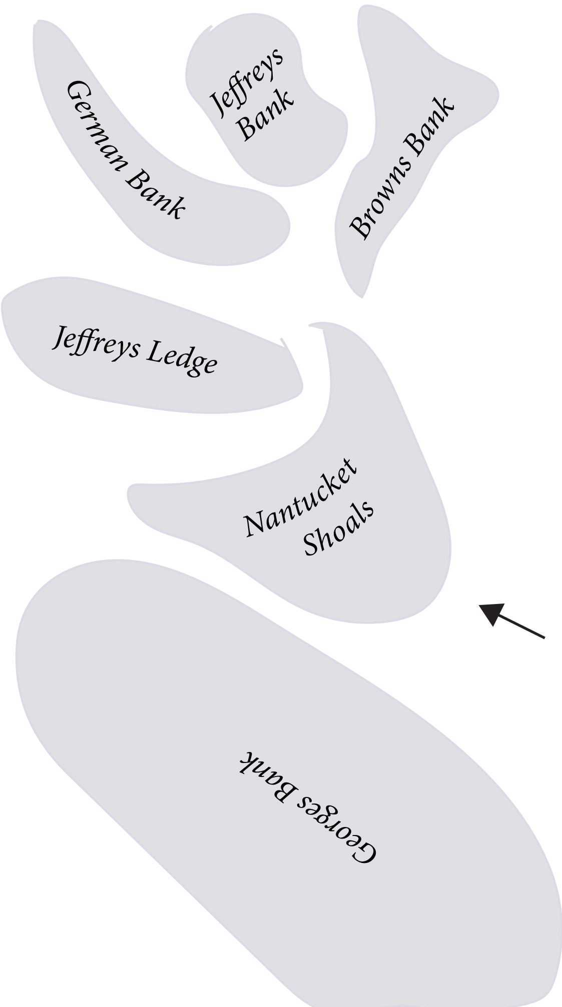
Background Information

The shores of Atlantic Canada, and the coasts of Maine, New Hampshire, and Massachusetts down to the tip of Cape Cod make up the boundaries of the GoM. There is a complex flow of freshwater from the region's large rivers as well as freshwater from the Gulf of St. Lawrence and snow and ice melt from the arctic delivered by the Labrador Current. The GoM has some of the world's strongest tides and offshore wind resources. This unique geographical system is unlike any other in the world.

Activity

- Instruct students to work together to put the GoM together
- Hand out the GoM felt pieces to all students
- Students may work together or individually to create their GoM felt diagram
- After students have successfully completed their felt diagram, have students label each piece of their diagram using small Post-it Notes.
- Once students are familiar with the different elements of the GoM, have students remove the labels and practice building the GoM using the unlabeled pieces.
- As a challenge, have students team-up and time each other to see how fast they can successfully build their GoM felt board.
- As a writing exercise, students will answer the following questions:
    - ▹ Why it is important to understand the physical structure of the GoM? Remind students to think about the connections between the "natural" and "political" sides of the GoM. (Possible answer: if you are a fisherman or aquaculturist, it is important to understand the tides, currents, water quality, bottom type, etc. so you are profitable in your catch/harvest. You must also be aware of the regulations where you fish or where your aquaculture site is located. Fishing in state waters is different from fishing in federal waters.)
    - ▹ What are the political boundaries in the GoM and what does that mean for fisheries management? (Possible answer: political boundaries include New England states, and the Maine/Canadian border. There are different fishery management systems for state waters, federal waters and international waters).
    - ▹ What features and processes in the Gulf of Maine affect water flow? (Possible answer: currents, tides, bottom type, depth)
    - ▹ How might freshwater input from rivers affect the water in the Gulf of Maine? (Possible answer: freshwater may affect temperature, salinity, pH, oxygen, CO_2)


Gulf Stream
Continental Shelf
Nova Scotia Current
Nova Scotia
New Brunswick
Bay of Fundy Current
German Bank
Browns Bank
Georges Bank
Eastern Maine Coastal Current
Jeffreys Bank
Western Maine Coastal Current
Jeffreys Ledge
Nantucket Shoals
ME
Quebec
VT
NH
MA
RI
CT



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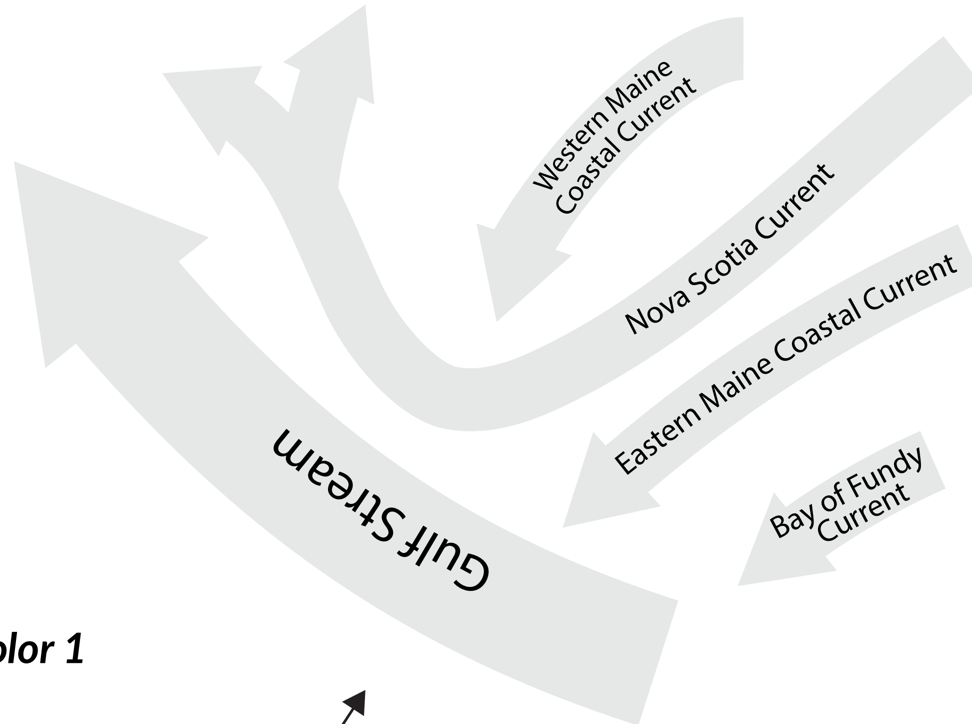

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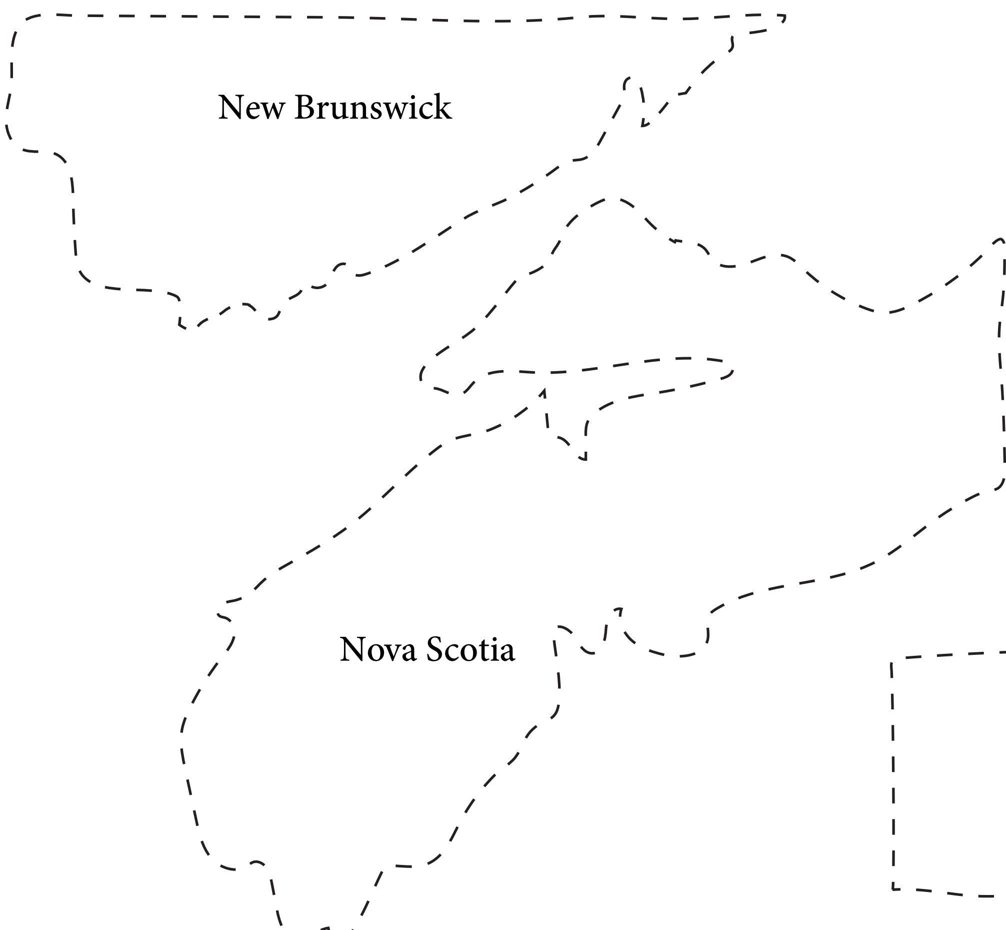
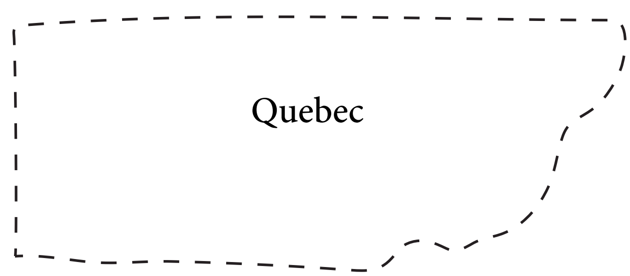
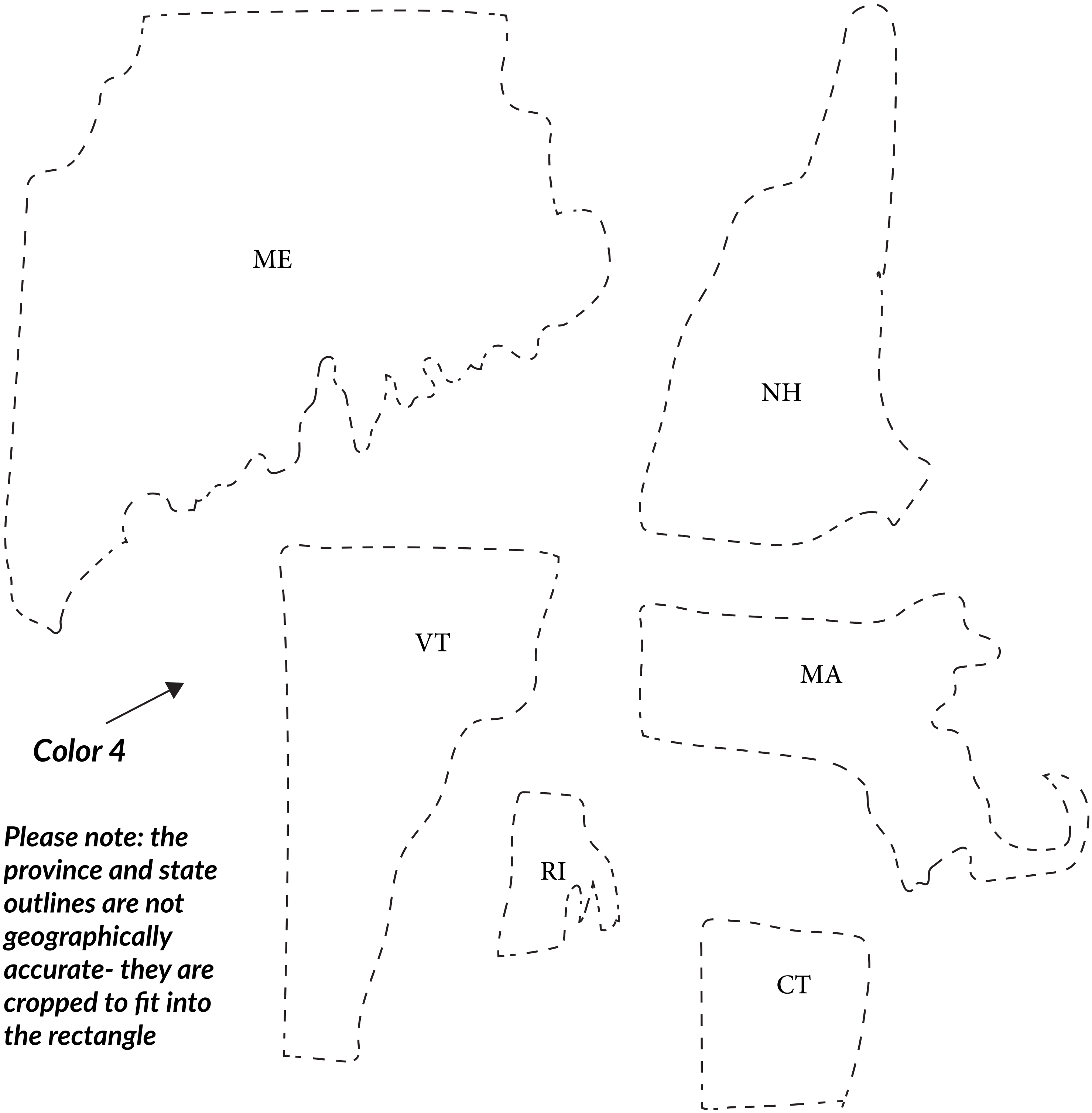


Please note: the province and state outlines are not geographically accurate- they are cropped to fit into the rectangle

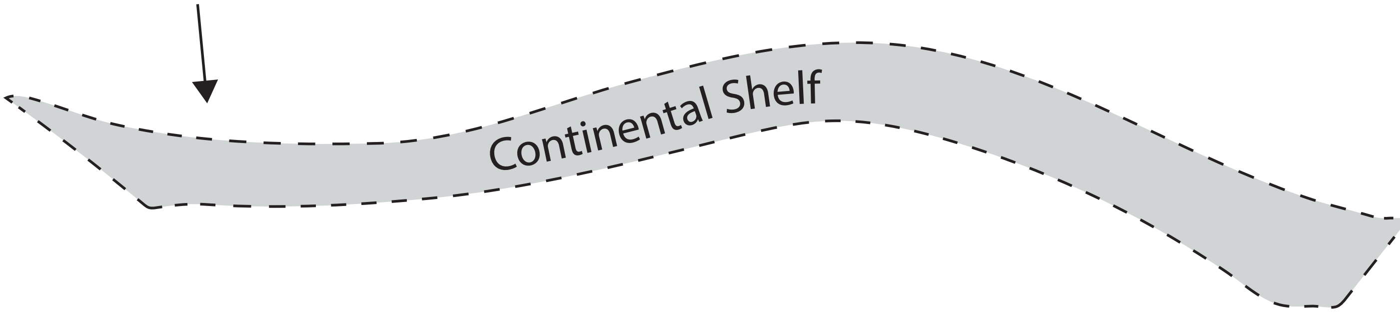




Color 4

Please note: the province and state outlines are not geographically accurate- they are cropped to fit into the rectangle

Color 5



Extension

- Hang up the newly created GoM felt boards around the room and use them for future conversations about the changes scientists, fishermen and citizens are seeing in the GoM.
- Have each student group “adopt a buoy” and mark it on their felt boards using (http://www.neracoos.org/realtime_map). Over the course of a week or several weeks, have students record the water temperature or other parameters.
- Have students make predictions on the changes they may see in the data. For example, will temperature increase/decrease over a period of time? Do students think there will there be a continuation of this trend?
- At the end of the collection timeframe, have students present their findings to the class.

Name: ____ Date: ____________________

Adopt a buoy

As an introduction to ocean observing systems, you will explore the NERACOOS database to understand the different ocean observing systems and the parameters used. Once you are familiar with the database, you will "adopt" a buoy of your choice in the GoM and record corresponding data using this guide.

What is NERACOOS?
NERACOOS is a robust regional ocean observing system that collects and delivers real-time weather and ocean data, including waves, wind direction, water and air temperature, currents and visibility in the Northeast. These data are collected from numerous buoys and stations throughout the GoM. Its mission is "to produce, integrate and communicate high quality information that helps ensure safety, economic and environmental resilience, and sustainable use of the coastal ocean.

Your Mission
Divide into teams and explore the NERACOOS website: http://www.neracoos.org/
Click on the logos to find out more about waves, water level, wind, temperature, currents data. Write down one interesting fact for each of the following categories:

Waves

Water Level

Wind

Temperature

Currents

More data...

Name: ____ Date: ____________________

Navigate to the following website: http://www.neracoos.org/realtime_map
Choose either a red (Gulf of Maine) or yellow (NOAA) buoy and click on it. Record below the most recent data for each parameter at the buoy you chose. Do this three different times throughout the day or at the beginning of each day over the course of a week.

Buoy Location
Latitude:
Longitude:

Observation 1	Observation 2	Observation 3
Date:	Date:	Date:
Time:	Time:	Time:
Wind Speed:	Wind Speed:	Wind Speed:
Wind Direction:	Wind Direction:	Wind Direction:
Wind Gust:	Wind Gust:	Wind Gust:
Wave Height:	Wave Height:	Wave Height:
Wave Period:	Wave Period:	Wave Period:
Air Temperature:	Air Temperature:	Air Temperature:
Air Pressure:	Air Pressure:	Air Pressure:
Visibility:	Visibility:	Visibility:
Water Temperature:	Water Temperature:	Water Temperature:
Salinity:	Salinity:	Salinity:
Other Parameters?	Other Parameters?	Other Parameters?

Name: ____ Date: ____________________

Writing Prompt

Take some time to look over your data and use the following guiding questions to help you write a short description of what you found.

- What did you notice after the end of the data collection period?
- Were data similar or did things change over time?
- Why is it important to monitor buoy data?
- How might these data be used by fishermen or aquaculturists?

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Climate of Change Part IV: The Future of Aquaculture

Lesson Plan

Ocean Chemistry 101

Essential Questions

- Why is it important to understand ocean chemistry?
- How does ocean chemistry impact life in the ocean?

Overview

Kelp aquaculture is a new and growing industry in Maine. Because kelp is a macroalgae, it requires different growing conditions than shellfish or finfish. Many kelp aquaculturists start growing kelp in a laboratory setting and set out the seeds in the fall. Over the winter, the kelp grows and is ready to harvest in early spring. Kelp is unique in that it absorbs nitrogen (N), phosphorus (P) and carbon dioxide (CO_2), all of which are harmful to the environment in excess amounts. Once the kelp is harvested, the nitrogen, phosphorus, and carbon dioxide that were absorbed from the plant are physically removed from the ocean environment. Kelp acts like a bio extractor, which may benefit the surrounding environment. Currently, research is being done in Casco Bay to see how many nutrients and how much carbon dioxide kelp farms can actually absorb, and if they can counteract the harmful effects of ocean acidification.

There are three parts to this lesson. The first part focuses on the key terms in the kelp section of the film (minutes 2:37 – 3:40). Students will have a short discussion about what they learned, using the guiding questions the teacher provides (see below). The second part of the lesson allows students to explore the chemistry and atomic structures of elements N and P, and the compound, CO_2 and the significance of these two elements and compound. The final portion of this lesson is a hands-on activity in which students examine a piece of sugar kelp (*Saccharina latissima*). There are two extensions to this lesson; one on marine toxins and water quality monitoring, and one on ocean acidification in the Gulf of Maine.

Objectives

- Students will explain the structure and properties of the elements N, P and CO_2 and the process by which kelp absorbs excess N, P and CO_2 in the ocean.
- Students will describe the anatomy and functions of sugar kelp (*Saccharina latissima*).

Standards

Next Gen Science Standards:
- MS-PS1-1. Develop models to describe the atomic composition of simple molecules and extended structures.
- HS-PS1-1. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.
- HS-LS1-2. Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.

Duration

80 Minutes

Subjects

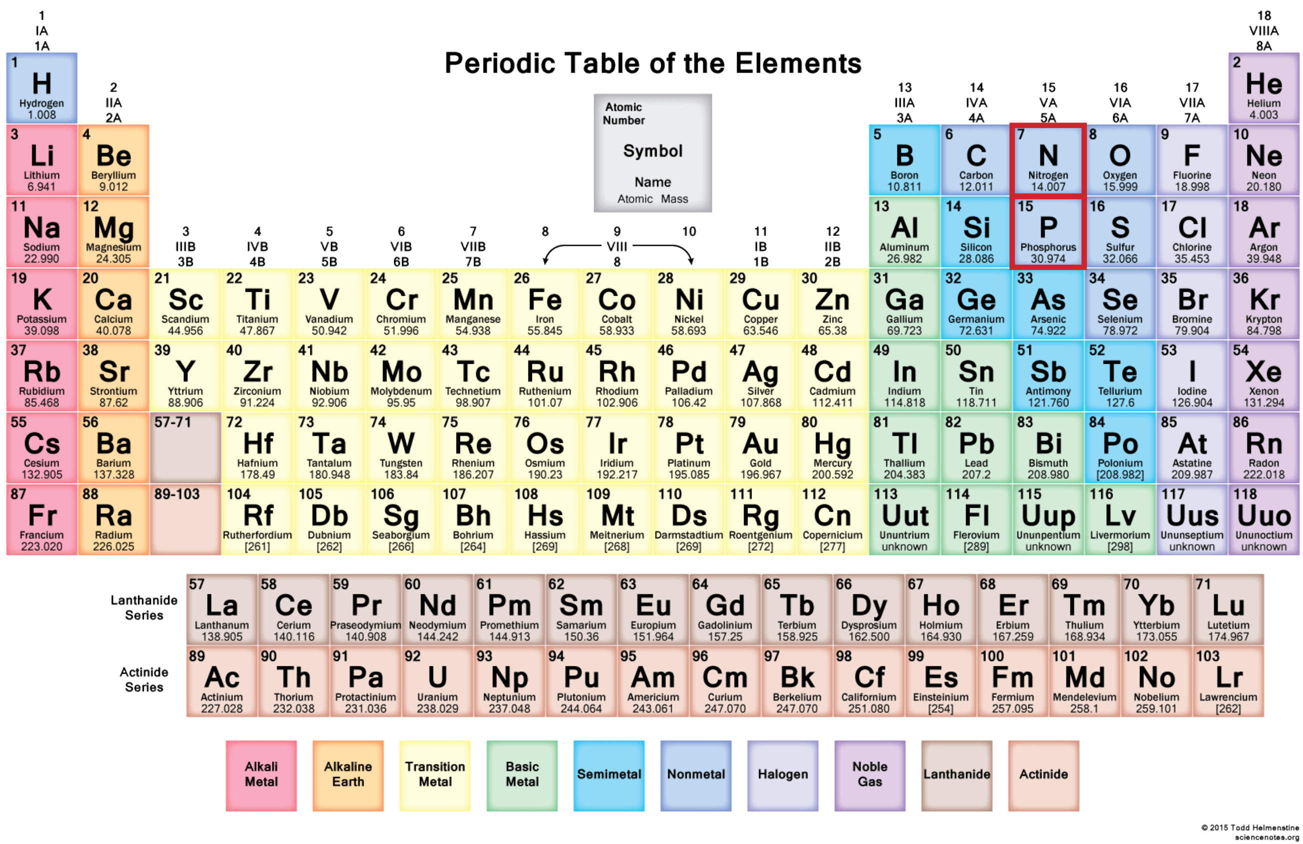
- Ecology
- Chemistry
- English Language Arts

Materials

- Periodic table (handout, or in classroom)
- Large, thin piece of sugar kelp (can be found at low tide or in shallow running water, but may be hard to find depending on your location and tide cycle)
- Beaker
- Hotplate or Bunsen burner to heat water
- Paint brushes

Activity

- Begin the lesson by watching the film, then ask the class what key words they remember hearing from the video related to chemistry and/or biology and write them on the board. The following are some helpful terms to focus on:
    - ▹ kelp farms
    - ▹ climate change
    - ▹ ocean acidification
    - ▹ excess nutrients
    - ▹ Nitrogen
    - ▹ Phosphorous
    - ▹ CO_2
    - ▹ bio extractor
- What is unique about kelp aquaculture in Maine and how does it benefit the surrounding environment?
    - ▹ 29th country in the world to start farming seaweed
    - ▹ $7.2 billion to the farming industry
    - ▹ Domestic alternatives to imported Asian seaweed
    - ▹ 90,000lbs of kelp harvested each year
    - ▹ Kelp absorbs N, P and CO_2 from the surrounding environment; three things that we have a little too much of in our bays along the coast of Maine.
- Have students look up N and P in the Periodic Table of Elements. Where are these elements found? What are the similarities and differences between these elements?



- N and P are in Group 15 or (5A), which is generally known as the nitrogen family. All elements in this group have five electrons in their outermost energy shell. However, these elements are not in the same period, meaning they have a different number of energy shells. Each new period row represents a new energy shell. N has 2 energy shells and P has 3 energy shells.

- Have students determine the atomic structure and electron configuration of N and P.
    - Nitrogen electron configuration 1s2 2s2 2p3
    - Phosphorus 1s2 2s2 2p6 3s2 3p3
- Have students draw or build a CO_2 molecule.
    - O=C=O
- Once students understand the basic framework of the two elements and the compound, they are ready to make the connection back to the film. Ask students how N and P end up in the ocean? Provide students with the following article if they need help (EPA Nutrient Pollution).
- Now bring out a piece of sugar kelp for students to examine. Ask students how kelp absorb nutrients. Unlike land-based plants, kelp species do not absorb nutrients from their holdfasts (they do not have roots); they absorb nutrients through all parts of their tissue, which is why they are so efficient at absorbing N, P and CO_2.
- The teacher will do the following demonstration:
    - Heat up a beaker of water, until it is steaming hot (not boiling)
    - Dip a piece of sugar kelp into the water and remove quickly
    - What has changed? If done correctly, the piece of sugar kelp should turn bright green (see photo below)
    - Now, dip the paint brush into the hot water and write your name on a new piece of sugar kelp. Have students take turns to write their names on pieces of sugar kelp
    - Ask students why they think the kelp is turning bright green. Is it a chemical reaction?
- Scientists are not completely sure why kelp turns green when dipped in hot water. We do know that there are two photosynthetic pigments that color kelp: cholorophyll-a and fucoxanthin, which is a carotenoid (the same class of pigments that make carrots orange). Chlorophyll-a is the pigment that is primarily responsible for photosynthesis, while fucoxanthin plays a supporting role in photosynthesis and is therefore called an "accessory" pigment. Chlorophyll-a is a green pigment and fucoxanthin is a brown pigment. It is not clear why fucoxanthin's olive brown color is dominant before heating and chlorophyll-a's bright green color is dominant after heating. Both pigments are present in kelp before it is heated and the hot water somehow "unmasks" the green chlorophyll-a.
    - For more information on pigments, visit http://www.ucmp.berkeley.edu/glossary/gloss3/pigments.html
- As a closing exercise, ask students why it is important to study and understand the chemistry of seawater.

Extension 1: Animal-environmental connections

Essential Questions:
- What are marine toxins and how are they harmful to humans?
- What are some different marine toxins common in Maine?

Marine toxins are naturally occurring chemicals that can contaminate certain seafood products. The seafood contaminated with these chemicals frequently looks, smells and tastes normal. When humans consume contaminated seafood, sickness or even death can result.

Water quality is a key component to successful aquaculture. Without taking the proper action to monitor and track water quality, farmers have the risk of losing most or all of their crop. They also have the risk of making people sick if they consume contaminated aquaculture products.

Students will choose a marine toxin from the list below to research. The final product is either a written or oral report. Good research skills and written communication are key to successful reports. Students may choose from the following:

- Common marine toxins in Maine:
  - Paralytic shellfish poisoning
  - Amnesic shellfish poisoning
- Marine toxins in the U.S.
  - Scombrotoxic fish poisoning (fin fish)
  - Ciguatera poisoning (reef fish)
  - Neurotoxic shellfish poisoning

A useful place to start research is the MaineHealth Works on Wellness's website.

Extension 2: Ocean acidification

Essential Questions:
- What is ocean acidification (OA)?
- Why should fishermen be aware of OA?
- How may it affect fisheries/businesses?

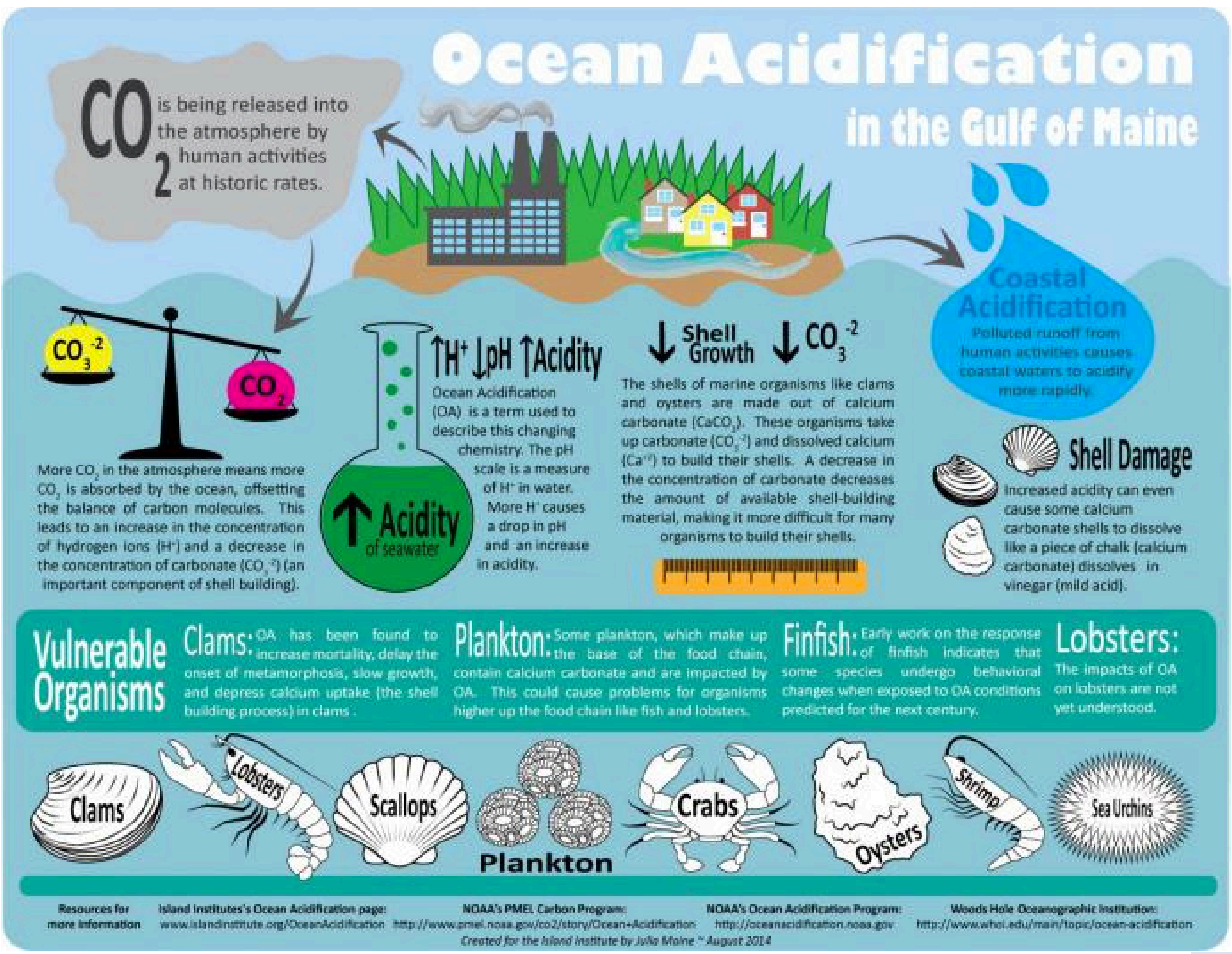
What is ocean acidification? According to NOAA's National Ocean Service, ocean acidification refers to a reduction in the pH of the ocean over an extended period of time, caused primarily by uptake of CO_2 from the atmosphere.

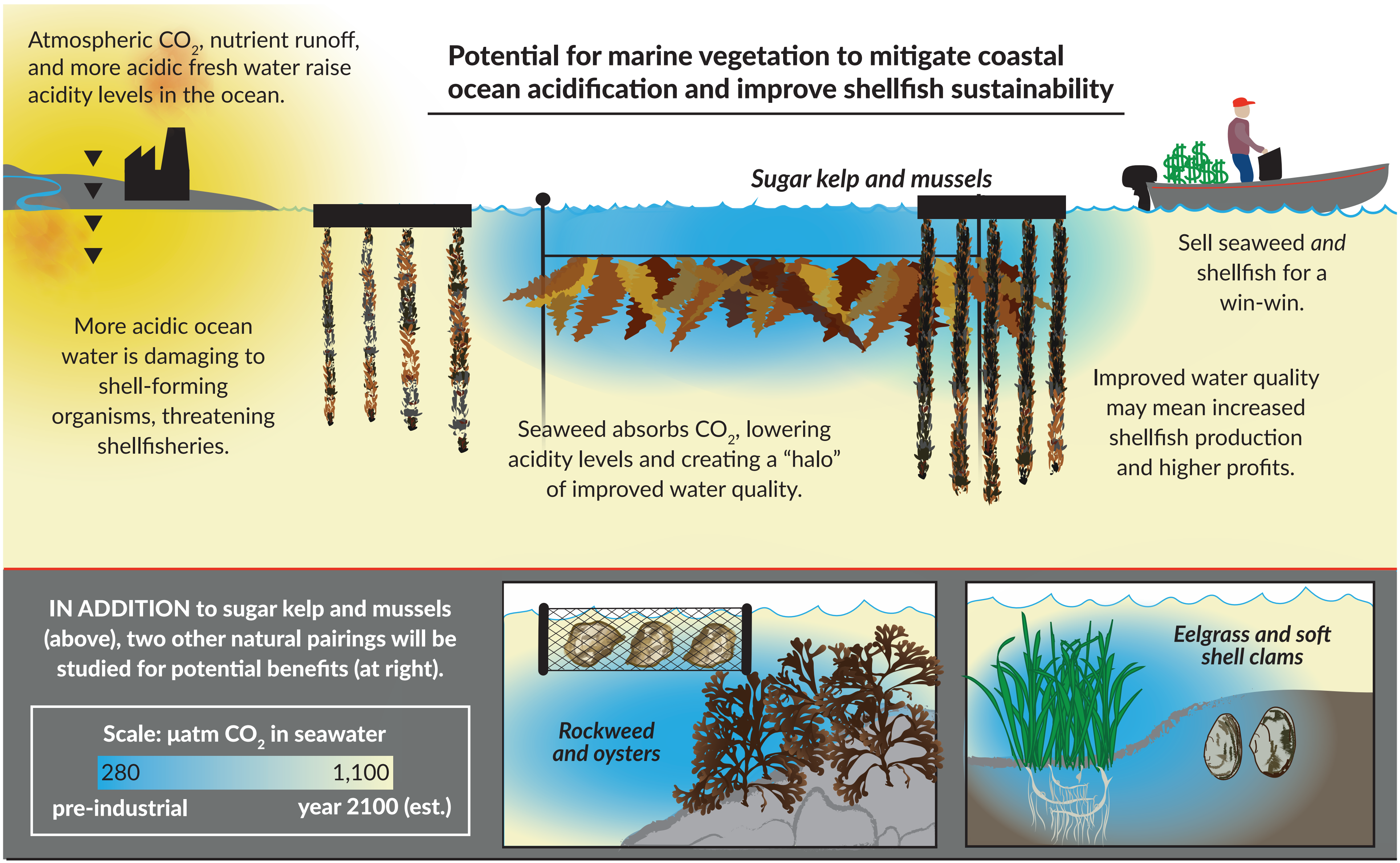
- To begin this lesson, have students watch "A Climate Calamity in the Gulf of Maine Part 2: Acid in the Gulf" by O'Chang Studios.
- After viewing the film, hand out the "Ocean Acidification in the Gulf of Maine" diagram and review the cycle of ocean acidification.
- Have students then focus on the chemistry of OA and answer the following questions:
  - How much CO_2 is absorbed in the ocean? (answer: 25%)
  - What happens to the CO_2 that is absorbed in the ocean? What is the chemical reaction (write the formula)? (answer: CO_2 binds with seawater and forms carbonic acid $CO_2 + H_2O \rightarrow H_2CO_3^-$)

- ▹ What happens when this acid breaks down? (answer: carbonic acid can breakdown (dissociate) into bicarbonate, which can then dissociate into carbonate ions ($H_2CO_3^- \rightarrow H^+ + HCO_3^-$). In other words, carbonic acid releases H^+ that combine with carbonate that is naturally occurring in the water, inhibiting the vital molecule calcium carbonate.)
- ▹ Write the formula for calcium carbonate (answer: $CaCO_3^{2-}$)
- ▹ Why is calcium carbonate an essential molecule in the marine environment? (answer: this molecule is the foundation for all shell-producing organisms; with fewer calcium carbonate molecules, shell-producing organisms have to spend more energy for shell production, which slows down growth)

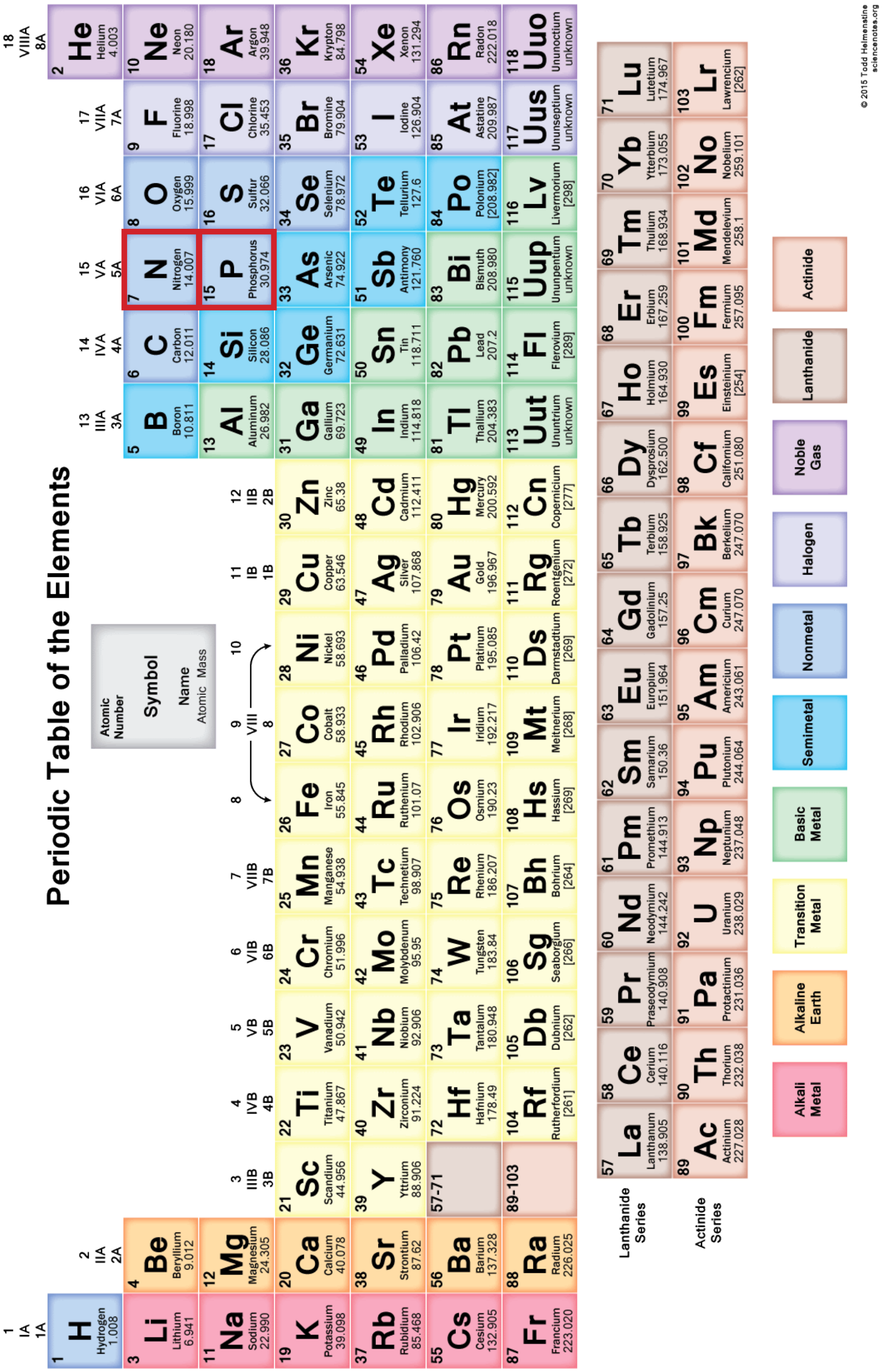
This link has good information and lesson plan ideas for teaching the chemistry behind ocean acidification.

- Once students have an understanding of the basic chemistry behind OA, have students explore the Northeast Coastal Acidification Network (necan.org) to see what research is occurring in the Gulf of Maine.
- Writing exercise:
    - ▹ What can we do to slow the process of OA?
    - ▹ Why should fishermen be aware of OA?
    - ▹ Is kelp aquaculture harmful or beneficial to the marine environment? (Provide students with the kelp/OA diagram on the following page.)





Potential for marine vegetation to mitigate coastal ocean acidification and improve shellfish sustainability
Atmospheric CO2, nutrient runoff, and more acidic fresh water raise acidity levels in the ocean.
More acidic ocean water is damaging to shell-forming organisms, threatening shellfisheries.
Sugar kelp and mussels
Seaweed absorbs CO2, lowering acidity levels and creating a "halo" of improved water quality.
Sell seaweed and shellfish for a win-win.
Improved water quality may mean increased shellfish production and higher profits.
IN ADDITION to sugar kelp and mussels (above), two other natural pairings will be studied for potential benefits (at right).
Scale: µatm CO2 in seawater
280
1,100
pre-industrial
year 2100 (est.)
Rockweed and oysters
Eelgrass and soft shell clams


Periodic Table of the Elements
Atomic Number
Symbol
Name
Atomic Mass
Lanthanide Series
Actinide Series
Alkali Metal
Alkaline Earth
Transition Metal
Basic Metal
Semimetal
Nonmetal
Halogen
Noble Gas
Lanthanide
Actinide
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Climate of Change Part IV: The Future of Aquaculture

Lesson Plan

Marine Ecosystems: Sea urchins, kelp and lobster

Essential Questions

- Since the ocean is so large, why do small changes make a difference?
- How do humans interact with the marine ecosystem?
- What is ecosystem-based management?

Overview

Students will gain a better understanding of the intricacies within the Gulf of Maine marine ecosystem after completing this lesson. A classic example of how small changes can affect an entire ecosystem is the sea urchin-kelp story in Maine. Following the collapse of the cod fishery in Maine, green sea urchin populations exploded. The ecosystem became an urchin-dominated system. In the 1980s, fishermen discovered the high value of harvesting sea urchins and the aggressive overharvesting of the green sea urchin resulted in massive declines along the coast. Because urchins are grazers (they eat kelp and other macroalgae), the decline of the urchin population resulted in a shift towards a kelp forest ecosystem. Most fishermen today report seeing a lot of kelp and few urchins. The relatively new kelp forest system is the perfect environment for American lobster and crabs, both of which are natural predators of urchins. This is an example of a tipping point in an ecosystem, shifting from an urchin-dominated system to a dense kelp forest system.

What can we learn from this story? Does it make sense to manage individual species or an ecosystem as a whole? There is a new movement to shift from single species management to Marine Ecosystem-Based Management (EBM). According to the Scientific Consensus Statement on Marine Ecosystem-Based Management, "EBM is an integrated approach to management that considers the entire ecosystem, including humans. The goal of EBM is to maintain an ecosystem in a healthy, productive and resilient condition so that it can provide the services humans want and need. EBM differs from current approaches that usually focus on a single species, sector, activity or concern; it considers the cumulative impacts of different sectors". In New England there is work being done to transition to this management framework. It will take a lot of effort and it is expensive to implement but once it is established, EBM has the potential to greatly benefit all who rely on a healthy ocean for their livelihoods.

There are two parts to this lesson. The first half of the lesson is devoted to the urchin-kelp story. Teachers can use the resources below to introduce this topic and help students understand the lessons learned from this story. The second half of the lesson is a hands-on activity from NOAA that will allow students to model a marine food web and a potential ecosystem collapse. Students will write an explanation of what they think might happen if a small change were to occur in the marine ecosystem in their backyards.

Objectives

- Students will explain recent changes in the Gulf of Maine ecosystem with regard to ground fish, sea urchins and kelp.
- Students will describe the human factor in the changing GoM ecosystem and the role that EBM could have on the GoM ecosystem.

Standards

Next Gen Science Standards:

- MS-LS2-4. - Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
- HS-LS2-6. Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.
- HS-LS4-5. Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.

Duration

60-80 Minutes

Subjects

- Ecology
- Biology
- English Language Arts

Materials

- Vocabulary handout
- Urchin-kelp diagram handout
- Jenga game
- Markers
- Scissors
- Glue or tape
- 1 stack of Jenga playing cards: Whale Jenga: A Food Web Game

Background Information

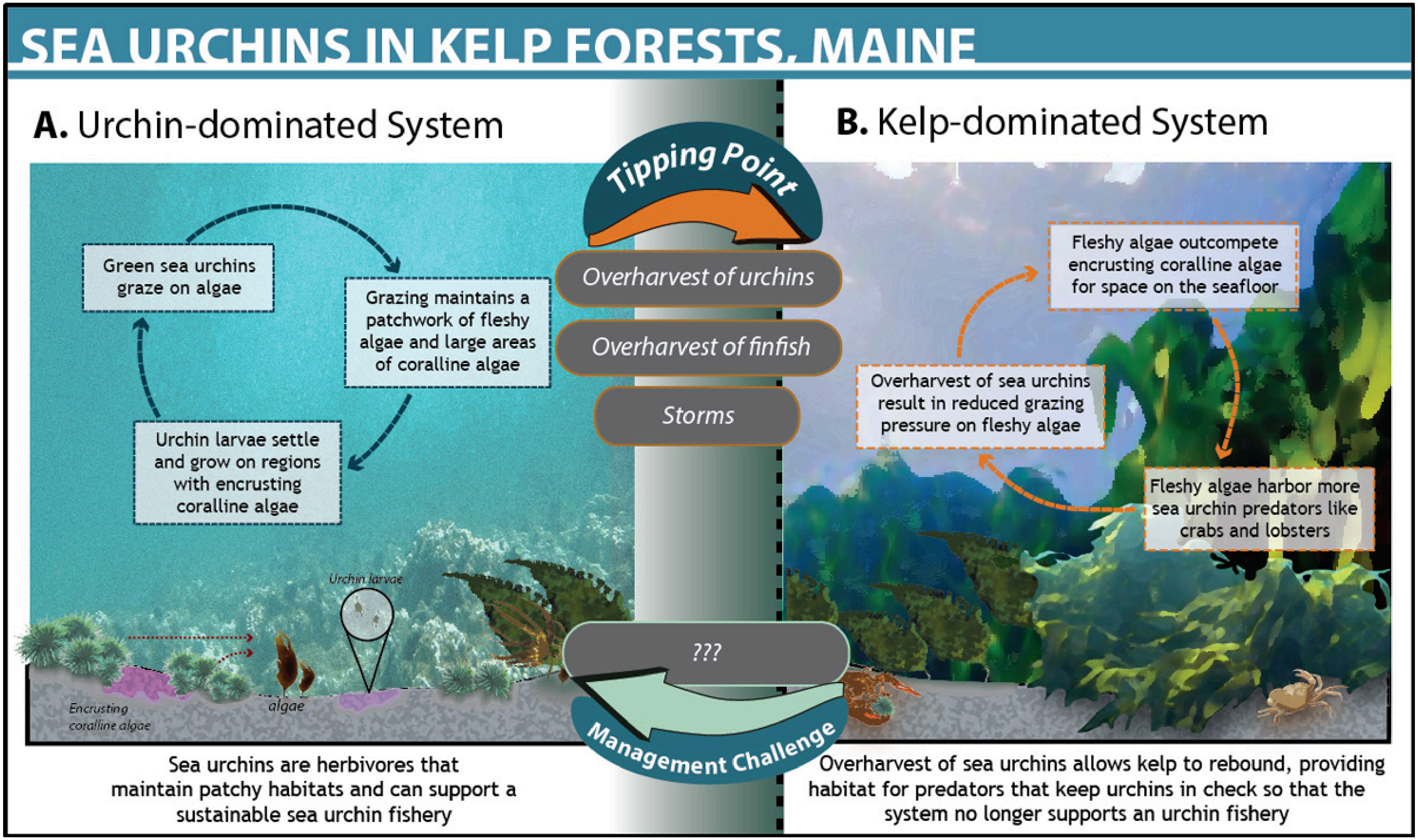
The urchin-kelp story is complicated but Ocean Tipping Points has summarized the concepts into a one-page document. The diagram on the next page was also created by Ocean Tipping Points.

There are certain vocabulary words that students will have to learn in order to be successful in this lesson. Teachers may either provide the definitions of each term or have students define them on their own. For younger students, teachers may provide the vocab matching handout (see below).

Vocabulary

- Food web – complex interaction of food chains; all the feeding relations of a community taken together; includes production, consumption, decomposition and the flow of energy
- Ecosystem based management (EBM) – an environmental management approach that recognizes the full array of interactions within an ecosystem, including humans, rather than considering single issues, species or ecosystem services in isolation
- Macroalgae – large algae, often living attached in dense beds
- Ecological tipping point – an event in which an ecosystem experiences a shift to a new state, with significant changes to biodiversity and the services to people
- Maximum sustainable yield –maximum number or amount of a species that can be harvested each year without steady depletion of the stock; the remaining stock is able to replace the harvested members by natural reproduction
- Herbivore/herbivory – an animal that consumes only plants
- Trophic level – is the position of an organism in a food chain or food (trophic) pyramid

The hands-on food web game that students will play was developed by NOAA and is a fun game to play with both young and more advanced students. Students will use the game Jenga to learn about the marine food web and how small changes in the food web can have large effects in the ecosystem.


SEA URCHINS IN KELP FORESTS, MAINE
A. Urchin-dominated System
Green sea urchins graze on algae
Grazing maintains a patchwork of fleshy algae and large areas of coralline algae
Urchin larvae settle and grow on regions with encrusting coralline algae
Urchin larvae
algae
Encrusting coralline algae
Sea urchins are herbivores that maintain patchy habitats and can support a sustainable sea urchin fishery
Tipping Point
Overharvest of urchins
Overharvest of finfish
Storms
???
Management Challenge
B. Kelp-dominated System
Fleshy algae outcompete encrusting coralline algae for space on the seafloor
Overharvest of sea urchins result in reduced grazing pressure on fleshy algae
Fleshy algae harbor more sea urchin predators like crabs and lobsters
Overharvest of sea urchins allows kelp to rebound, providing habitat for predators that keep urchins in check so that the system no longer supports an urchin fishery

Activity

PART I

- Introduce and discuss the urchin-kelp story. Pass out the diagram and use the following questions to start classroom discussion:
  - ▹ Why did the collapse of the cod fishery lead to an increase in urchin populations? (Cod were predators and ate urchins to control population numbers.)
  - ▹ What are the interactions between urchins and kelp? (Urchins eat or graze on kelp; without urchins, kelp can continue to grow.)
  - ▹ What are the lessons learned from this story? (Small changes in the ecosystem can lead to entire ecosystem shifts.)
  - ▹ Is there a similar situation happening right now with lobsters? (Warming waters are allowing new predators, like black seabass, to come into the Gulf of Maine and prey on baby lobsters.)
- Post important vocabulary words. Students may work together to define these terms or it can be a classroom activity. For younger students, provide the vocabulary matching handout.

PART II

- To demonstrate the complex nature of ecosystems, play the Whale Jenga: A Food Web Game, created by NOAA. Students will have to understand the importance of ecosystem health and structure to fully benefit from this activity. It is also recommended to review the vocabulary before playing the game.
- Once the game has been completed students will reflect on the following questions:
  - ▹ What surprised you during the game?
  - ▹ What are the interactions between human uses and the marine environment?
  - ▹ What are some questions you would like to investigate further?
- Students will write an explanation of what they think may happen if a small change were to occur in the ecosystem at the local level (in their backyards). This change could be either negative (i.e. overfishing) or positive (i.e. more beach clean-up days). Remind students to use the vocabulary that was introduced in this lesson and to think back to the food web game.

Additional Resources

- https://umaine.edu/news/blog/2013/03/25/flipped-and-locked/
- http://www.cobscook.org/sea-urchins-part-i
- http://www.ecologyandsociety.org/vol17/iss2/art15/

Answer key for worksheet on next page:

Answer	Term	Letter	Definition
C	**Macroalgae**	A	A complex of interacting food chains; all the feeding relations of a community taken together; includes production, consumption, decomposition and the flow of energy
F	**Herbivore**	B	An environmental management approach that recognizes the full array of interactions within an ecosystem, including humans, rather than considering single issues, species or ecosystem services in isolation
E	**Maximum sustainable yield**	C	Large algae, often living attached in dense beds
G	**Trophic level**	D	An event in which an ecosystem experiences a shift to a new state, with significant changes to biodiversity and services to people
A	**Food web**	E	Maximum number or amount of a species that can be harvested each year without steady depletion of the stock; the remaining stock is able to replace the harvested members by natural reproduction
D	**Ecological tipping point**	F	An animal that consumes only plants
B	**Ecosystem based management (EBM)**	G	The position of an organism in a food chain or food (trophic) pyramid

Match the term with its definition

___	**Macroalgae**	**A**	A complex of interacting food chains; all the feeding relations of a community taken together; includes production, consumption, decomposition and the flow of energy
___	**Herbivore**	**B**	An environmental management approach that recognizes the full array of interactions within an ecosystem, including humans, rather than considering single issues, species or ecosystem services in isolation
___	**Maximum sustainable yield**	**C**	Large algae, often living attached in dense beds
___	**Trophic level**	**D**	An event in which an ecosystem experiences a shift to a new state, with significant changes to biodiversity and services to people
___	**Food web**	**E**	Maximum number or amount of a species that can be harvested each year without steady depletion of the stock; the remaining stock is able to replace the harvested members by natural reproduction
___	**Ecological tipping point**	**F**	An animal that consumes only plants
___	**Ecosystem based management (EBM)**	**G**	The position of an organism in a food chain or food (trophic) pyramid

ISLAND INSTITUTE

Climate of Change Part IV: The Future of Aquaculture

Lesson Plan

Seaweed vs. Plants

Essential Questions

- What are the differences and similarities between seaweeds and land plants?
- What is the composition of a kelp (macroalgae) cell and how does it differ from a plant cell?
- What are some different human uses for seaweed?

Overview

Seaweeds have been harvested and used throughout the world for centuries and are highly valued in many countries today. The U.S. is just now discovering the many health benefits seaweeds provide and there is a shift towards kelp aquaculture. But what are seaweeds? Are they water plants or a species of their own? How are seaweeds used in today's society? In this lesson, students will investigate these questions. To begin the lesson, the teacher will introduce the differences between seaweeds and land plants, followed by a microscope lab exercise where students will be using their different senses to identify the differences and similarities between sugar kelp (*Saccharina latissima*) and a sunflower leaf (or geranium or other house plant leaf). As a wrap-up activity, students will be able to taste test seaweed salad (provided by the teacher). Students are encouraged to use their five senses during this lesson to help sharpen observation skills.

Objectives

- Students will demonstrate the differences and similarities between plants and macroalgae.
- Students will assess different types of cells under a microscope.
- Students will explain the process of photosynthesis for both plants and macroalgae.

Standards

Next Gen Science Standards:
- MS-LS1-1 - Conduct an investigation to provide evidence that living things are made of cells; either one cell or many different numbers and types of cells
- MS-LS1-6 - Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms
- HS-LS1-5. Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.

Duration

60-80 Minutes

Subjects

- Biology
- Chemistry
- English Language Arts

Materials

Materials for each section are listed on page 30

NOTE: *It is important that students know how to properly use a microscope in Part II of this lesson. If students do not have the necessary skills, do the microscope activity together as a class. The teacher can demonstrate how to prepare slides and use a microscope. Students may take turns looking through the microscope, comparing and contrasting the kelp slide and the germanium leaf slide.*
Below are useful resources on how to use a compound light microscope:

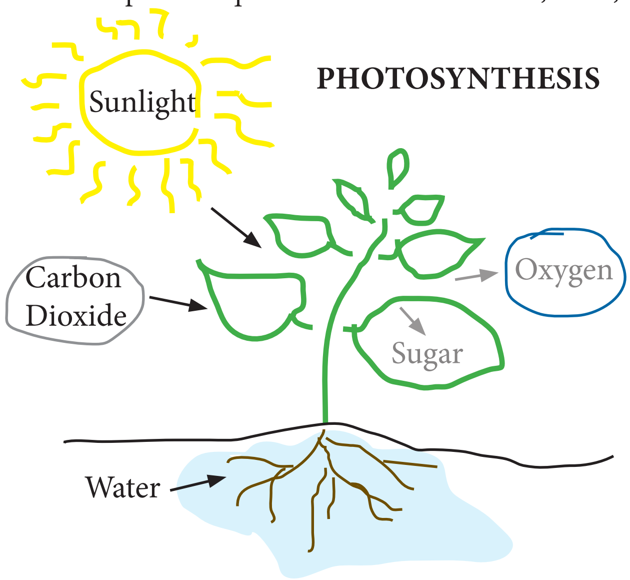
- http://www.scienceprofonline.com/microbiology/how-to-use-compound-microscope.html
- https://www.youtube.com/watch?v=b6_SuhG_VPM

Background Information

PART I – Differences and similarities between seaweeds and land plants
Seaweeds are a type of macroalgae; they are not plants, even though at first glance they appear to be plants. There are many differences between seaweeds and plants, mostly at the cellular level. (Source: http://simply-science-nbep.blogspot.com/2011/06/algae-vs-plants.html)

Seaweed
- May be unicellular, colonial, or multicellular
- Holdfast, staples and blades compose multi-cellular algae
- Each cell in algae must obtain its own nutrients from water for survival
- Photosynthetic
- Can be found on land and water
- Reproduction: can reproduce through tiny spores or by replication of the growth of broken pieces

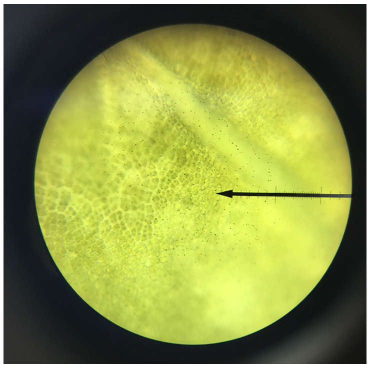
Land Plants
- Only multi-cellular
- Roots, stems, leaves, flowers, fruits, seeds and cones
- Have vascular systems
- Photosynthetic
- Can be found on land and water
- Reproduction: complex, multi-cellar reproductive systems and certain species require assistance from wind, birds, bugs or bats for pollination

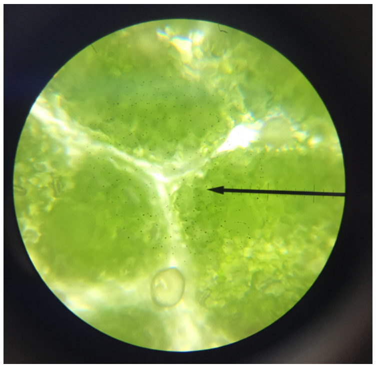


The main similarity between seaweeds and plants is that they are both photosynthetic. Both need sunlight for survival.
Chemical equation for photosynthesis:
$6H_2O + 6CO_2 \rightarrow C_6H_{12}O_6 + 6O_2$

For younger students, photosynthesis may be explained by the following:
water + carbon dioxide from atmosphere + sunlight → sugar + oxygen (see graphic at right or on page 32). Teachers may hand out the diagram for younger students, or draw/post in classroom.

PART II – Using observation and microscope skills
Students will first observe a small piece of sugar kelp and a sunflower leaf (or other house plant leaf) and draw pictures, using the worksheet as a guide. Next, students will look at the sugar kelp and leaf under a microscope. Students can either prepare the wet mount slides themselves or the teacher can prepare slides ahead of time before the start of the lesson. Students will draw pictures of what they observe under the microscope at 40x TM (total magnification) objective lens (if there is time, allow students to view the slides at different magnifications). Students should use the worksheet as a guide to help them with this step.
Below are examples of what students should observe under the microscope:

Sugar kelp 

Sunflower leaf 

PART III – Eating seaweeds and other uses

The teacher will prepare the following seaweed salad recipe the night/morning before the lesson. The teacher can also print copies of the "cookbook" created by Oceanside West High Schools students. Printed double-sided, it will fold in half to form a book.

Cucumber Wakame Salad (8-10 small portions)

- 2-3 medium cucumbers, julienned
- 3oz rehydrated/softened wakame seaweed, cut into 2-inch lengths
- 6 Tbs rice vinegar
- 2 Tbs toasted sesame oil
- 2 Tbs tamari or soy sauce
- 2 tsp fresh grated ginger
- 1/4 cup lightly toasted sesame seeds

Mix vinegar, oil, soy sauce and ginger. Add cucumber and wakame and mix well, then top with toasted sesame seeds.

This recipe was developed by students from Oceanside High School West at Herring Gut Learning Center. This activity is a fun way to introduce students to a new food. Before sampling the salad, ask students what they think it will taste like. Have them make observations about the appearance of the salad – what color is it, what does it smell like, what looks the same/different from a "regular" lettuce salad? Make sure to provide small cups/dishes and utensils for each student and be sure to have students wash their hands after the microscope lab activity. Once students have made their observations, they may now try the salad. While sampling the salad, ask students what other products seaweed may be found in. These videos may inspire creative thinking around the many uses seaweed provides.

Bath and spa seaweed products:

- https://www.youtube.com/watch?v=c9EmV6LCV8E (2:14 minutes)
- https://www.youtube.com/watch?v=UXrM9TFrrc0 (12:24 minutes)

Once finished, ask students to come up with a list of words describing the salad (ex. salty, chewy, flavorful) and avoid words judging the salad (ex. gross or good). Hand out the cookbook that students at Oceanside West High School created. This may inspire students and their families to cook with seaweed.

Materials

PART I

- Kelp and land plant diagram (for teacher to use as guide)
- Draw kelp and land plant diagrams on the board with blank spaces to label the different parts
- Chemical equation for photosynthesis
- Lab worksheets

PART II

- Microscope station materials:
  - Microscope and slides for each station
  - Kelp samples for microscope (slides can be made ahead of time depending on students' microscope skills)
  - Houseplant leaf cross-section for microscope (slides can be made ahead of time depending on students' microscope skills)

PART III

- TEACHER PREP: the night/morning before this lesson prepare the seaweed salad (see above for recipe)
- Seaweed salad samples for students to taste in small cups with forks or chopsticks
- Handwashing station
- Oceanside West High School Seaweed Explorations cookbook to share with students

Activity

PART I

- Begin the lesson by drawing or posting the kelp and plant diagram (see next page) on the board as a discussion topic
- Do you think these diagrams are plants, algae or animals? (Kelp is a seaweed that is a type of macroalgae (macro means big; micro means small); the flowering plant is a land plant.)
- What type of seaweed/plant species is this? (Sugar kelp; flowering plant)
- How are seaweeds and plants different (see above table for reference); how are they similar? (Both undergo photosynthesis to convert sunlight to energy.)
  - ▹ What is photosynthesis? For older students, ask a volunteer to write the chemical equation on the board: $6H_2O + 6CO_2 \rightarrow C_6H_{12}O_6 + 6O_2$
  - ▹ Water + carbon dioxide from atmosphere + sunlight → sugar + oxygen
- Hand out worksheets to students and explain the lab procedures:
  - ▹ First, have students break up into small teams
  - ▹ Have groups go to a station around the room; the stations are all the same, each with a piece of sugar kelp, a geranium leaf, slides and a microscope
  - ▹ Students will first examine each sample, using their eyes only and draw what they observe
  - ▹ Using the microscope, students will than examine the slides and draw what they observe

    **Remind students to use proper microscope handling procedures

PART II

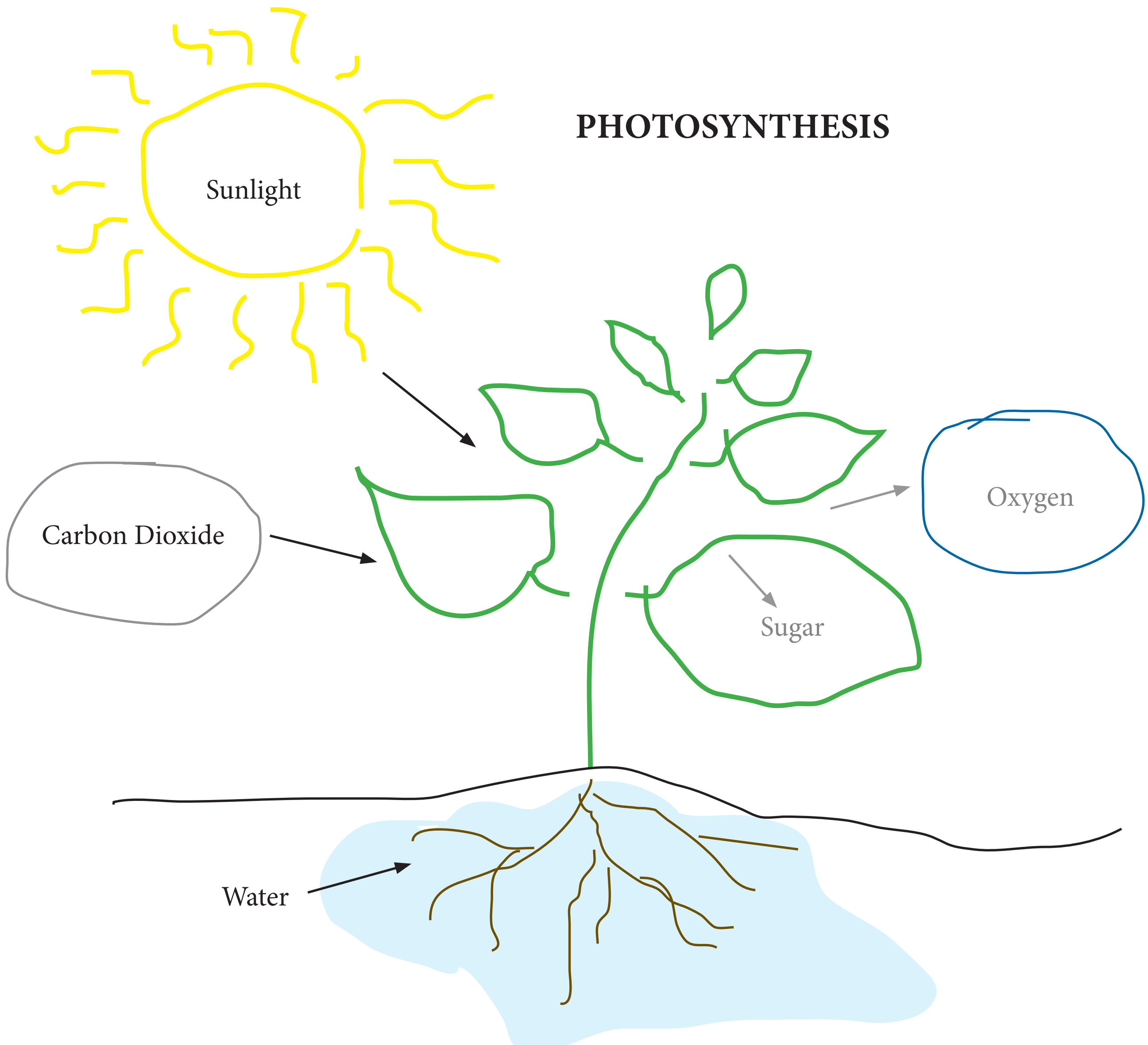
- Allow students about 15 minutes at their station, making sure they have adequate time to make all observations and to fill in their worksheets
- Once students have completed their observations, come back as a group to discuss the following questions:
  - ▹ Was it easier to use the microscope or the naked eye to make observations?
  - ▹ What was the difference between the kelp and geranium samples? What were the similarities?
  - ▹ What are some special adaptations that kelp have to survive in the ocean? (holdfasts to attach to ocean bottom, fronds to absorb sunlight)

PART III

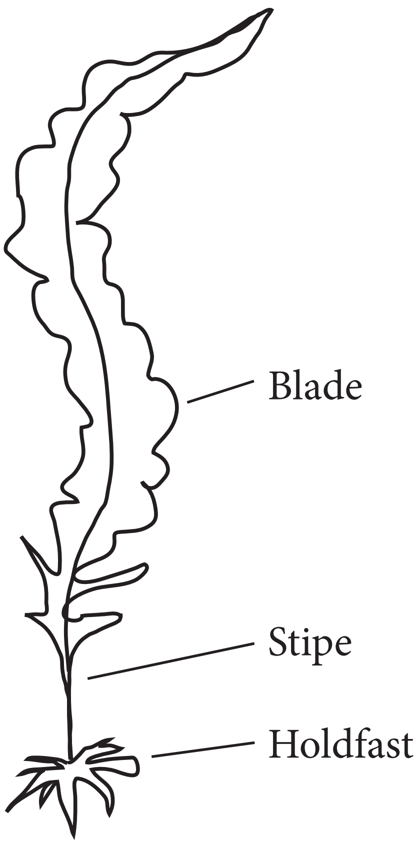
- Now it is time for taste testing! Make sure students wash their hands before sampling the seaweed salad
- Put a sample of the seaweed salad in a small cup for each student
  - ▹ Ask students what other products seaweed may be found in. Besides food, what are some other human uses kelp can provide? (toothpaste, cosmetics)
  - ▹ These videos may inspire creative thinking around the many uses seaweed provides.
  - ▹ Bath and spa seaweed products:
  - ▹ https://www.youtube.com/watch?v=c9EmV6LCV8E (2:14 minutes)
  - ▹ https://www.youtube.com/watch?v=UXrM9TFrrc0 (12:24 minutes)
- After allowing students to sample the salad, ask students their opinions about the flavor, texture, appearance, etc.
- Pass out seaweed cookbooks to students and inspire them to create their own seaweed snack.

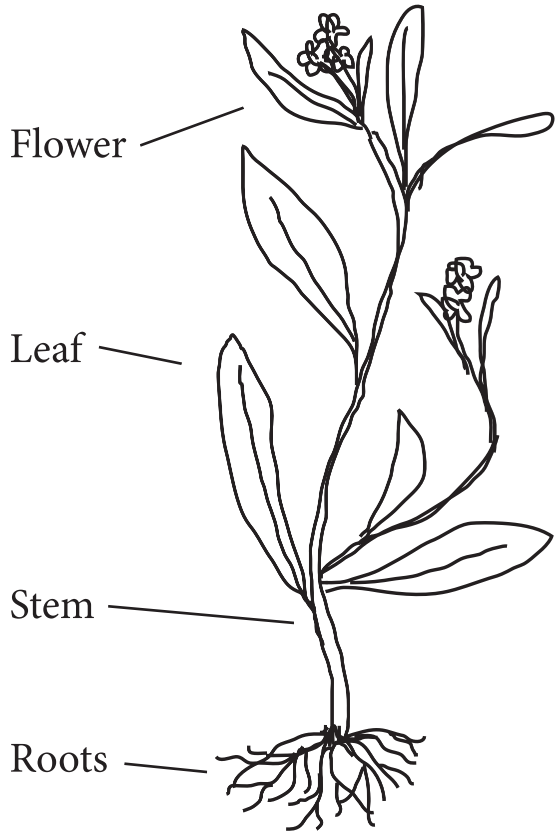
Additional Resources

- NOAA lesson plan: Taking a closer look at seaweeds
- SlideShare: Similarities and dissimilarities of algae and plants


Sunlight
PHOTOSYNTHESIS
Carbon Dioxide
Oxygen
Sugar
Water

Kelp vs. Plant





Seaweeds:

- may be unicellular, colonial, or multicellular
- holdfast, staples and blades compose multi-cellular algae
- each cell in algae must obtain its own nutrients from water for survival
- photosynthetic
- can be found on land and water
- reproduction: can reproduce through tiny spores or by replication of the growth of broken pieces

Plants:

- only multi-cellular
- roots, stems, leaves, flowers, fruits, seeds and cones
- have vascular systems
- photosynthetic
- can be found on land and water
- reproduction: complex, multi-cellar reproductive systems and certain species require assistance from wind, birds, bugs or bats for pollination

Source: http://simply-science-nbep.blogspot.com/2011/06/algae-vs-plants.html

Notes

Oceanside West High School Seaweed Explorations

April 5, 2013

Guest Instructor: Genna Cherichello
Volunteer: Anna Wind

Free Draw

Notes

Miso Soup with Dulse (Serves 1)

1 cup water
1 Tbsp miso
1/4 cup sliced dulse seaweed
2 slices kombu
2 Tbsp minced scallion
1 Tbsp grated ginger
2 Tbsp diced tofu

Boil the water with the kombu to make dashi. Remove water from heat and strain out kombu. Chop kombu into thin strips. Stir miso into remaining broth, and add the rest of the ingredients.

Notes:

This is what I know: acid rain is leaching the trace minerals out of the soil and washing the nutrients downstream to the ocean. The seaweeds capture them. And I? I go about in my little boat, harvesting them, drying them, and sending these nutrients back upstream...upstream, from earth's ocean bloodstream back into humanity's salty bloodstream, by way of amending the soil, by way of fertilizing the plants in the garden, by feeding the animals on the farm, and by supplying nourishing food for the table...food that is nutrient-dense, like wild herbs from the sea. -Larch Hanson, a sustainable seaweed harvester

Seaweed Nutrition

Seaweed is incredibly **nutrient dense**. One gram of seaweed fulfills the daily *iodine* requirement, important for thyroid and brain health. It is also a rich source of *calcium* and *protein*. The plentiful *fiber* in seaweed is soluble (versus insoluble), which turns into a gel and slows down digestion. Almost all seaweeds contains vitamins A, B, C, E, and K, and minerals sodium, potassium, magnesium, copper, and zinc.

Dulse: very high in vitamins B6 and B12

Kelp: high in soluble and insoluble fiber

Kombu: high in iodine (which helps thyroid control metabolism)

Wakame: highest calcium of all seaweed, contains *fucoxhanthin* which improves insulin resistance

Nori: richest protein source of sea flora, omega-3 fatty acids, and vitamin C (antioxidant)

Cucumber Wakame Salad (Serves 8-10)

2-3 medium cucumbers, julienned
3 oz. rehydrated and softened wakame seaweed, cut into about 2 inch lengths
6 Tbsp rice vinegar
2 Tbsp sesame oil, toasted
2 Tbsp tamari or soy sauce
2 tsp freshly grated ginger
1/4 cup lightly toasted sesame seeds

Mix vinegar, oil, and ginger in a bowl.Add cucumber and wakame in the bowl and mix well. Top with sesame seeds and toss together.

Notes:

Kelp Noodle Pad Thai (Serves 8-10)

1 1/2 cup all natural peanut butter
1/2 cup coconut milk
1 teaspoon ground ginger
2 cloves garlic
2 tsp Sriracha
2 tbsp soy sauce
1 tsp + 2 Tbsp sesame oil
2 tbsp brown sugar
2 tbsp cilantro
Juice of 1 lime
1 C water (give or take)
2 pounds kelp noodles
1/2 cup peanuts
1 small green cabbage (or napa cabbage)
1 bunch scallions or green onions
2 tablespoons sesame seeds

Defrost kelp noodles and drain. Combine first ten ingredients in a blender (reserve 2 Tbsp sesame oil), and add water until desired consistency is reached. Sauté cabbage in remaining sesame oil. Combine kelp noodles and peanut sauce in a bowl and toss with cabbage, sliced scallions, peanuts, and sesame seeds.

Notes:

Name: ______________________________________ Date: ____________________

Seaweed or Plant?

- You will be examining a piece of sugar kelp (*Saccharina latissima*) and a geranium leaf to determine if there are differences between the two samples. Begin by making a prediction about what you think you may observe after examining both specimens.
- Take a few minutes to then carefully look at the samples up close, using your eyes only and draw a diagram. What do you observe?
- Now, use the compound microscope at 40xTM and observe the kelp and geranium samples. Record what you observed.

Predictions:

Kelp (with my own eyes)	**Plant (with my own eyes)**

What differences did you observe without using a microscope?

Kelp (with microscope at 40xTM)	**Plant (with microscope at 40xTM)**

What differences did you observe when looking through a microscope?

ISLAND INSTITUTE

Climate of Change Part IV: The Future of Aquaculture

Lesson Plan

Geography of Aquaculture

Essential Questions

- How long and in what ways have humans been involved in aquaculture as a way to produce food?
- What are the differences between wild harvest and seaweed aquaculture businesses?
- Where are some local shellfish and seaweed aquaculture businesses located along the coast of Maine?
- How might the presence of an aquaculture business affect a community?

Overview

Aquaculture is not a new technology. Sea vegetables, fish, and shellfish have been grown for hundreds, even thousands, of years throughout the world. China and Japan are examples of countries that have used and relied upon aquaculture for generations. This lesson will first focus on the history and origins of aquaculture followed by a geography exercise where students will locate and identify different countries that use aquaculture on a regular basis. Students will then locate and identify local aquaculture businesses along the coast of Maine using maps or charts. The goal of this lesson is to help students understand that aquaculture is not a new technology and that the U.S. is just now transitioning to this practice, with Maine being the leader in shellfish and kelp aquaculture.

Objectives

- Students will recognize that humans have been practicing aquaculture for thousands of years.
- Students will explain the difference between wild harvest and aquacultured seaweed.
- Students will identify aquaculture businesses in their community and explain the impact of those businesses on the community.

Standards

Next Gen Science Standards:
- N/A

Duration

80 minutes (can be divided into two lessons)

Subjects

- Geography
- Social Studies
- English Language Arts

Materials

- Aquaculture history flashcards- print and cut out prior to lesson
- YouTube video of scallop ear-hanging technology
- List of Maine aquaculture businesses
- Map of the Maine coast handouts
- Notecards
- Writing prompt

Background Information

Aquaculture began around 3,500 BCE with carp cultivation in China. Many southeast Asian countries have been practicing aquaculture ever since. By the early 1800s aquaculture practices were seen in the U.S., and in 1853 an Ohio trout farm became the first in the U.S. to artificially fertilize fish eggs. Since then, new aquaculture methods and technologies have been popping up around the world.

One example of new technology is sea scallop "ear-hanging" in Japan. Team members of the Maine Sea Grant visited the state of Aomori Prefecture in Japan in 2010 to learn more about this new technology and to collect ideas to bring to Maine's growing aquaculture industry. This YouTube video is a compilation of highlights from this trip.

Over the past decade there have been numerous aquaculture businesses started along Maine's coast. Most of these businesses were started using new technology and many of the growers were uncertain about the success rates of their newly developed farms. Through trial and error, these farms have grown into viable businesses. The following is a partial list of aquaculture businesses in Maine:

"As part of an ongoing and productive relationship, a delegation from Maine visited its sister-state of Aomori Prefecture, Japan, in 2010. Part of the trip was to re-visit the Japanese scallop aquaculture industry, with a highlight of stopping at the manufacturing facility of a premier gear supplier, specific to the scallop aquaculture technique called 'ear-hanging.'"
- Dana Morse, University of Maine Cooperative Extension, Maine Sea Grant

AQUACULTURE BUSINESSES IN MAINE

Edible seaweeds:
Gulf of Maine, Pembroke
Maine Coast Sea Vegetables, Hancock
Maine Fresh Sea Farms, Damariscotta
Ocean Approved, Portland
VitaminSea, Buxton
Wild Ocean Aquaculture, Portland
Atlantic Holdfast Seaweed Company, Penobscot Bay
Maine Seaweed, Steuben
North Haven Seaweed, North Haven
Shearwater Ventures, Long Island
IronBound Island Seaweed, Winter Harbor

Oysters:
The Maine Oyster Trail (A detailed list of oyster aquaculture businesses in Maine):
http://www.seagrant.umaine.edu/maine-oyster-trail#learn
Capitan B Oyster Company, Chebeague Island
Siren's Sea Farm, Yarmouth
Mook Sea Farms, Walpole
Basket Island Oysters, Peaks Island
Chebeague Island Oyster Company, Chebeague Island

Mussels:
Marshall Cove Aquaculture, Islesboro
Bang's Island Mussels, Portland
Calendar Island Mussel Company, Portland
Oceanville Seafood, Stonington

Activity

- Begin the lesson by dividing the class into small groups and hand out a deck of aquaculture flashcards to each group
- Have students work together to put the flashcards in sequential order.
- After 15 minutes, or until students have completed the task, see which group(s) successfully sequenced the cards
- Ask students the following questions:
    - Which countries were the first to start aquaculture? (China and southeast Asian countries)
    - When did aquaculture start being practiced in the U.S.? (early 1800s)
    - What surprised you/didn't surprise you after completing the sequencing? (i.e., Surprised to learn that seaweed farming started back in the 1600s)
    - How do you think aquaculture technology has changed over the years? (i.e., We are now better able to measure water quality, which allows for a healthier aquaculture product)
- One example of new technology is sea scallop "ear-hanging" in Japan. Introduce the short YouTube video to students:
    - Team members of the Maine Sea Grant visited the state of Aomori Prefecture in Japan in 2010 to learn more about this new technology and to borrow ideas to bring to Maine's growing aquaculture industry. This YouTube video is a short compilation of highlights from this trip
- Have a short discussion about what students learned from the video
    - Why did a team from Maine travel all the way to Japan? (They went to learn about the new technology they are using in sea scallop aquaculture in Japan that could be used in Maine)
    - What did this team learn from their trip? (Ear-hanging methods used in scallop aquaculture are successful in Japan and could be used in Maine; creative thinking can really pay off in the aquaculture business.)
    - How will this exchange trip help Maine aquaculture businesses? (By sharing ideas and learning from others, Maine aquaculture businesses can grow and diversify.)
- After the discussion, distribute the Maine coast aquaculture map worksheet. Have students work alone or in pairs to locate and pinpoint five Maine aquaculture businesses on the Maine map.
- Once students have identified the location of five aquaculture businesses, have students create a business card for one of the businesses:
- Hand out 3"x5" notecards to each student.
- The following information should be incorporated into the business card:
    - Name of business
    - Type of species that is grown (i.e., mussels, oysters, kelp, etc.)
    - Contact information
    - Creative slogan for business (created by students)
    - Students will have to do online research on the business they choose.
- After students have completed their business cards, have students do a short "sales pitch" for the class, stating why their aquaculture business is the best.
- As homework or as a class discussion, ask students the following question:
- How may the presence of an aquaculture business affect a community? Good responses should include the following:
    - Environmental (ocean acidification, climate change)
    - Regulatory (bay management and ocean planning; how the ocean space will be used by different user groups without conflict)
    - Business/economic (diversified fishery)
    - Cultural (community members supportive/opposed to an aquaculture operation)
    - Tourism (an aquaculture farm could become a possible interest to tourists)

Cultivation of carp begins in China using freshwater ponds and rice paddies	Oyster farming begins in Japan
Seaweed farming begins in Japan.	Fish farming in its modem form begins when a German farmer successfully gathers trout eggs, fertilizes them, and then grows the hatched fish to maturity.
Aquaculturists experiment with lobster and winter flounder aquaculture in New England.	Washington's oyster farming industry begins when Pacific oysters from Japan are placed in coastal waters.
Raft culture of scallops is developed in Japan.	The first commercial salmon farms are established in Norway and Scotland.

Mussel aquaculture develops on both coasts of the U.S.

The commercial farming of hard clams, or quahogs, begins in New England.

Shrimp farming industries in many parts of the world collapse due to outbreaks of disease.

Tuna farming, in which juvenile wild fish are captured and then fattened in cages, is established in Australia.

Maine begins commercial seaweed aquaculture.

Production of farmed salmon exceeds the amount of salmon caught in the wild.

Infectious salmon anemia (ISA) spreads to Maine, forcing salmon farmers to slaughter over 1 million fish.

Commercially farmed cod is available in the US for the first time.

Timeline of U.S. and World Aquaculture (events on cards are in bold text)

List from Alabama Cooperative Extension Service: http://www.aces.edu/dept/fisheries/education/documents/General_Aquaculture_Timeline.pdf

3500 BC
Cultivation of carp begins in China using freshwater ponds and rice paddies.

2500 BC
Hieroglyphics indicate tilapia were being farmed in Egypt.

2000 BC
Oyster farming begins in Japan.

746 AD
The first reference to clam culture appears in Chinese literature.

1400
Marine finfish aquaculture begins in Indonesia when young milkfish are trapped in coastal ponds at high tide.

1600s
Seaweed farming begins in Japan.

1733
Fish farming in its modern form begins when a German farmer successfully gathers trout eggs, fertilizes them, and then grows the hatched fish to maturity.

Early 1800s
Oyster farming is further developed by the French by placing strings of tiles in water for oyster larvae to settle on and then transplanting the larvae to protected beds.

Oyster farming expands to the Atlantic coast of the U.S.

1853
An Ohio trout farm becomes the first in the U.S. to artificially fertilize its fish eggs.

1880s
Aquaculturists experiment with lobster and winter flounder aquaculture in New England.

1909
The first commercial trout farm in the U.S. is established in Idaho.

1910
State and federal hatcheries in the U.S. develop channel catfish farming techniques.

1919
Washington's oyster farming industry begins when Pacific oysters from Japan are placed in coastal waters.

1930s
President Franklin D. Roosevelt's Farm Pond Program encourages the growth of the U.S. aquaculture industry by providing federal subsidies for building and stocking fishponds on farms.

Researchers in Japan make major advances in shrimp-farming techniques.

1934
Raft culture of scallops is developed in Japan.
1940s
Tilapia farming is introduced to the Caribbean, Latin America and the U.S.

1950s
Netpen aquaculture is introduced in Japan for the commercial culture of yellowtail.

1951
Intensive seaweed farming begins in China.

1960s
Commercial shrimp farming develops in Japan and soon begins in Ecuador and the U.S.

Late 1960s
Sea bass production begins in the Mediterranean.

The first commercial salmon farms are established in Norway and Scotland.

1970s
U.S. catfish farm acreage grows from 400 acres in 1960 to 40,000 in 1970.

After nearly collapsing due to disease and a saturated world salmon market, Norway grows to become the world's top salmon-farming nation.

Salmon farming expands to the U.S. and Canada.

Abalone hatcheries develop in California.

Mussel aquaculture develops on both coasts of the U.S.

1976
New Zealand's first commercial salmon farm is established.

World aquaculture production is estimated to be 6.1 million metric tons(mt).

1980s
The National Aquaculture Act of 1980 is passed in the U.S. to provide for the development of the aquaculture industry.

Sturgeon farming begins in California.

The commercial farming of hard clams, or quahogs, begins in New England.

1981
Manila clam farming begins in Washington and California.

1984
World aquaculture production reaches 10 million mt, contributing 12 percent of the world's aquatic food supply.

1985
Salmon farming is introduced in Australia.

Late 1980s
Shrimp-farming industries in Asia and South America undergo rapid expansion .

Early 1990s
World aquaculture production in 1990 is 13 million mt.

Research begins in the Mediterranean on the feasibility of off-shore aquaculture.

U.S. striped bass and tilapia aquaculture industries develop.

The Irish sea trout fishery collapses because of sea lice infestations believed to be caused by salmon farms.

Shrimp farming industries in many parts of the world collapse due to outbreaks of disease.

Alaska bans commercial netpen fish farms to protect its wild fisheries.

1991
Tuna farming, in which juvenile wild fish are captured and then fattened in cages, is established in Australia.

1992
Snapper aquaculture begins in Australia.

1994
Between 1984 and 1994, world aquaculture production grows 11 percent per year on average.

Maine begins commercial seaweed aquaculture.

1995
The British Columbia government places a moratorium on new salmon farm tenures in order to conduct an environmental review of the industry .

World aquaculture production is 24 million mt.

1996
Canadian researchers patent transgenic salmon.

1997
Canada announces plans to fund research in cod farming

1998
Sea bream culture grows from 110 mt in 1985 to 41,900 mt in 1998.

1999
World aquaculture production grows 154% during the 1990s. Production tops 33 million mt and contributes nearly one-third of the aquatic food supply.

Production of farmed salmon exceeds the amount of salmon caught in the wild.

2000
Farmed salmon production tops one million mt.

Research begins on new aquaculture species such as flounder, sablefish and halibut.

American aquaculturists induce spawning in cobia, marking the first step towards commercial cobia farming.

2001
Since 1989, close to three million Atlantic salmon are reported to have escaped from farms in British Columbia, Washington, Maine, and Scotland.

Infectious salmon anemia (ISA) spreads to Maine forcing salmon farmers to slaughter over 1 million fish.

2002
Traces of illegal antibiotics are detected in farmed shrimp imported from Asia.

Officials in British Columbia announce plans to lift the moratorium on new salmon farms.

Australia's bluefin tuna farmers produced 9,245 mt for a value of AU $260.5 million, a three-fold increase in five years.

2003
Salmon farmers in Maine are found in violation of the Clean Water Act and ordered to fallow their sites for two to three years and cease the use of European strains of fish at their farms.

Commercially farmed cod are available in the US for the first time.

Offshore fish farming projects, funded by NOAA, exist in Hawaii, New Hampshire, Puerto Rico, and the Gulf of Mexico.

Name: ____ Date: ____________________

AQUACULTURE BUSINESSES IN MAINE

Mark the location of five of the following businesses on the accompanying map. You will probably have to search for the locations online. Please note, this is NOT a complete list of aquaculture businesses in Maine.

Edible seaweeds:

Gulf of Maine, Pembroke
Maine Coast Sea Vegetables, Hancock
Maine Fresh Sea Farms, Damariscotta
Ocean Approved, Portland
VitaminSea, Buxton
Wild Ocean Aquaculture, Portland
Atlantic Holdfast Seaweed Company, Penobscot Bay
Maine Seaweed, Steuben
North Haven Seaweed, North Haven
Shearwater Ventures, Long Island
IronBound Island Seaweed, Winter Harbor

Oysters:

The Maine Oyster Trail (A detailed list of oyster aquaculture businesses in Maine):
http://www.seagrant.umaine.edu/maine-oyster-trail#learn
Capitan B Oyster Company, Chebeague Island
Siren's Sea Farm, Yarmouth
Mook Sea Farms, Walpole
Basket Island Oysters, Peaks Island
Chebeague Island Oyster Company, Chebeague Island

Mussels:

Marshall Cove Aquaculture, Islesboro
Bang's Island Mussels, Portland
Calendar Island Mussel Company, Portland
Oceanville Seafood, Stonington

Identify the location of five aquaculture operations on the Maine coast

Extension: Where in the world is aquaculture?

Essential Questions:

- Which countries practice aquaculture and why?

Using the aquaculture history flashcards, ask students to locate the different countries on a large world map. It could be a simple exercise where students gather around a large poster and work together to locate countries, or it could be more interactive, like the activity below, where students have to find the "coordinates" of each country. This also introduces and reinforces the concepts of latitude and longitude.

[Large world map exercise]()

ISLAND INSTITUTE

Climate of Change Part IV: The Future of Aquaculture

Lesson Plan

Aquaculture: Husbandry 101

Essential Questions

- What are the basic components of aquaculture husbandry?
- How might husbandry practices (good or bad) influence an aquaculture operation?

Overview

Husbandry is the care, cultivation and breeding of animals and plants, which is usually one of the first things you think about when starting an aquaculture business. When paired with strong financial management and sales and marketing, husbandry is part of a successful aquaculture business. Simply put, as a farmer, your goal is to keep your animals (or plants) at optimum health that will lead to a profitable harvest.

This activity is a short 45-minute lesson focused on the different aspects of husbandry. Students will use the *Aquaculture in Shared Waters: Husbandry* fact sheet to help them understand the basics of aquaculture husbandry. Topics covered in the fact sheet include choosing a site and the correct gear for your crop, the harmful effects of biofouling, predators and pests, farm biosecurity and record keeping.

Objectives

- Students will identify key aspects of the successful care, cultivation and breeding of plants and animals in an aquaculture setting.
- Students will describe best practices for keeping aquacultured plants and animals healthy.

Standards

Next Gen Science Standards:

- HS-LS2-6. Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.
- MS-LS2-5. Evaluate competing design solutions for maintaining biodiversity and ecosystem services.

Duration

45 Minutes

Subjects

- Science
- English Language Arts

Materials

- Aquaculture in Shared Waters: Husbandry fact sheet
- Blue, pink and yellow sticky notes for students (1 color for each student)

Background information

As community members begin to think about the future of the coast of Maine, many are turning to aquaculture. Some people are curious about starting a new business, others may know someone who is interested. Some just want to better understand what aquaculture looks like. To help answer these questions, the partners involved in the Aquaculture in Shared Waters project developed a fact sheet series that provides a jumping-off point for a more in-depth conversation about aquaculture.

These fact sheets can be found on the Island Institute aquaculture webpage, and below:

- Introduction to Aquaculture - what is needed to start a small operation in Maine
- Know Your Water - basic water quality monitoring techniques
- Husbandry - best practices for shellfish aquaculture
- The Business of Aquaculture - how to successfully develop and run a small aquaculture business
- Kelp Production - what is needed to start your own seaweed aquaculture operation

The Aquaculture in Shared Waters project is a National Sea Grant funded program to help prepare fishermen to start an aquaculture venture. Support from this project comes from partnerships between the following organizations: University of Maine School of Marine Sciences, Maine Sea Grant, University of Maine Cooperative Extension, Maine Aquaculture Association, Maine Aquaculture Innovation Center, Coastal Enterprises Inc., and the Island Institute.

Activity

- Before the start of the lesson, hand out the *Aquaculture in Shared Waters: Husbandry* fact sheet to each student
- Handout sticky notes to each student, making sure students have three different colored sticky notes.
    - ▹ Be sure to have extra sticky notes in case students need to make additional notes
- Students will then take time to read through the fact sheet and will work individually to answer the following and write their responses on their sticky notes:
    - ▹ This made me think of… (blue sticky)
    - ▹ I wonder… (pink sticky)
    - ▹ This information reminds me of the film… (yellow sticky)
- Once students have finished the activity, come back as a class and sort the colored sticky notes together on the board. In one column, put all the blue notes together, followed by the pink and yellow sticky notes. Are there similar questions and responses? Have students work together to create one question and/or response for each of the three colors.

If students finish ahead of time, have them read through the additional Aquaculture in Shared Waters fact sheets and have students do a similar sticky note activity.

Notes

Notes

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