North American Marine Environment Protection Association®

NAMEPA

2014 Lloyd's List Awards ENVIRONMENT AWARD WINNER

An Educator's Guide to the **Marine Environment**

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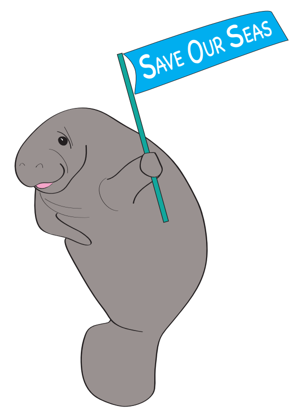
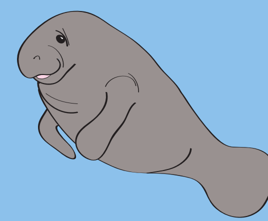


AN EDUCATOR'S GUIDE TO THE MARINE ENVIRONMENT



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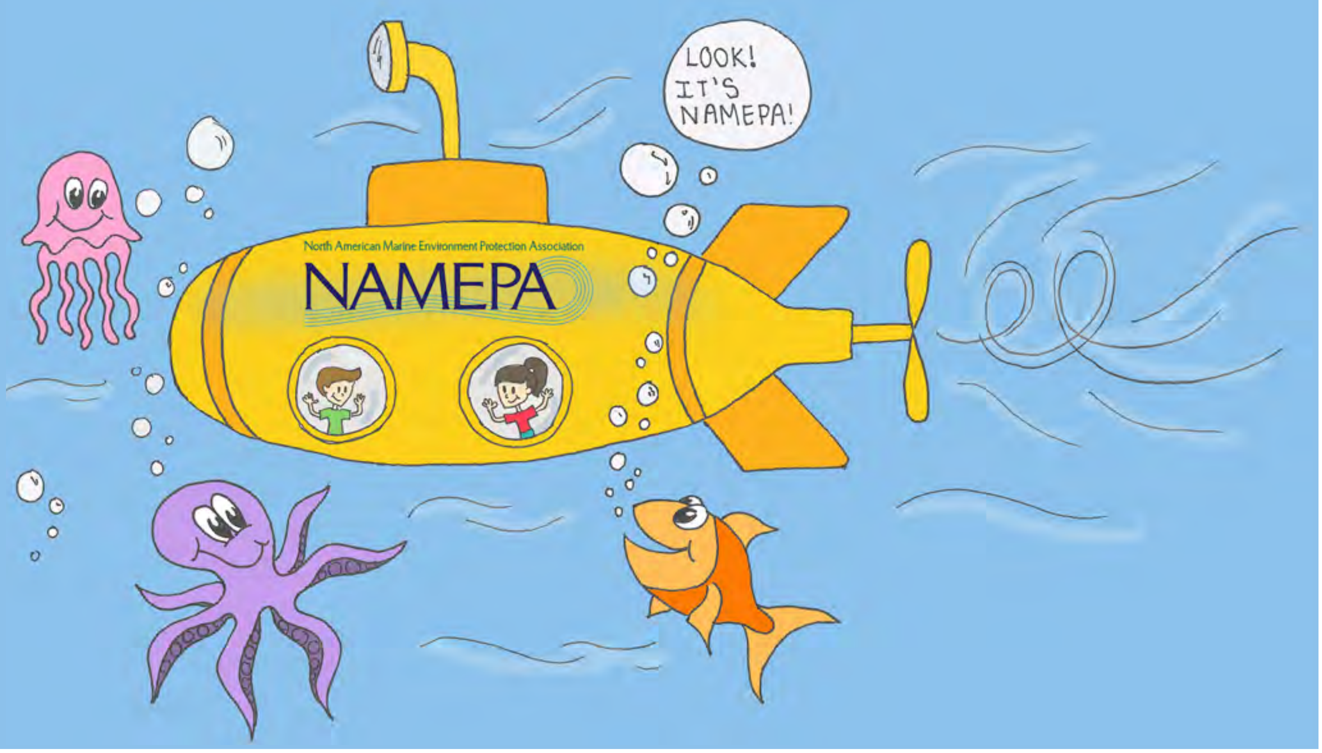


AN EDUCATOR'S GUIDE TO THE MARINE ENVIRONMENT

Introduction

To this day, the ocean remains a largely uncharted and unexplored frontier wilderness. It is home to some of the most biologically diverse ecosystems on the planet, and within those ecosystems are innumerable species scientists are now only beginning to identify. As the world's largest carbon sink, the ocean acts as a climate regulator as well as supplies us with more than half of the oxygen we breathe. Millions of people around the world depend on the ocean for food, medicine, recreation and transportation. As famous oceanographer Sylvia Earle wrote in her book, *The World is Blue,* "Everyone, everywhere is inextricably connected to and utterly dependent upon the existence of the sea" (Earle, 2010).

The vastness of the ocean has made it appear to be inexhaustible. However, in recent years, we have begun to understand the effects humans are having on this important global resource. Pollution, overfishing, climate change and loss of habitat are among the threats currently facing the world's oceans.

Fostering emotional bonds and connectedness between oceans and people is paramount to helping to preserve and protect our oceans and waterways. This guide is a great tool to use to introduce students to a variety of topics related to the marine environment. Through education and increased awareness, we can help to ensure that future generations will be able to enjoy the wonder and beauty of the oceans as we do.

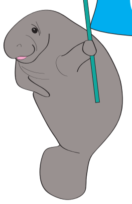
Painting by Kayla Delventhal

The North American Marine Environment Protection Association (NAMEPA) is a marine industry-led organization that works to educate seafarers, port communities and students about the need and strategies for protecting the marine environment. NAMEPA has created *An Educator's Guide to the Marine Environment* to provide educators with a tool to help students become more informed about ocean ecosystems and encourage environmental stewardship.

This easy-to-use guide was designed to provide maximum flexibility for educators in both formal and informal settings. It may be used as a standalone teaching tool or to supplement lessons in other areas. This guide includes lessons for students K-12 with a focus on STEM (Science, Technology, Engineering, Mathematics) and Next Generation Science Standards (NGSS) objectives.

This guide was published in 2015 and is the second learning guide published by NAMEPA, the first being *An Educator's Guide to Marine Debris,* published in partnership with the National Oceanic and Atmospheric Administration (NOAA) in 2014. To access digital copies of these guides, links referenced in this guide, or for additional information, visit www.namepa.net/education or www.namepajr.net. We hope to continue to update this guide with new resources.
If you used this guide or any of our education resources, please provide us with feedback by emailing Elise Avallon at e.avallon@namepa.net.

Ocean Acidification



1: SHELLS IN ACID

Grade Level: K-5
Time: 25-35 minutes

SUMMARY

In this lab, students will test the strength of normal seashells versus shells that have been soaked in vinegar to simulate the weakening effect of ocean acidification. Heavy books are used to demonstrate that shells that have been soaked in vinegar will crack more easily and hold less weight than shells that have not been in acidic conditions.

OBJECTIVES:

Students will:
• Identify the correlation between decreasing oceanic pH (ocean acidification) and the weakening of shells.
• Discuss the effect this could have on the health of shellfish in the world's oceans.

STEM APPLICATIONS:

• **Engineering** – Students will test the structural integrity and relative strength of shells that have been weakened by soaking in acid (vinegar) and comparing the value to normal shells.
• **Science** - Students will learn about ocean acidification and its effects on organisms with shells.

NGSS ALIGNMENT:

• **Practice 1.** Asking Questions and Defining Problems.
  • **K-2 –** Ask and/or identify questions that can be answered by an investigation.
  • **3-5 –** Identify scientific (testable) and non-scientific (non-testable) questions.
• **Practice 4.** Analyzing and Interpreting Data
  • **K-2 –** Record information (observations, thoughts, and ideas).
  • **3-5 –** Analyze and interpret data to make sense of phenomena using logical reasoning, mathematics, and/or computation.

VOCABULARY:

Brittle – Thin, breakable, fragile and/or easily cracked.
Calcium Carbonate – The natural substance that shells are made from.
Dissolve – To break down, either quickly or over time, due to a chemical reaction.
Ocean Acidification – A phenomenon that is currently being observed in the world's oceans wherein seawater absorbs carbon dioxide from the atmosphere and in turn becomes more acidic. The impacts to marine life are unknown, but a quick change in acidity could make it hard for marine organisms – especially shellfish – to survive.
Acid – A substance, like vinegar, with a low pH.
Invertebrate – Animals, including shellfish, that do not have a backbone.
Exoskeleton – A hard covering on the outside of an organisims body that helps give it structure and protect its body.

MATERIALS:

• White vinegar*
• Small, thin seashells*
• Non-reactive containers (glass beakers, Pyrex)*
• Water*
• Heavy books
• Paper towels

*Before beginning this activity, shells should be pre-soaked overnight in a 1:1 solution of vinegar and fresh water.

BACKGROUND:

Shell-forming organisms are especially at risk if the world's oceans continue to become more acidic. Their shells are made from a material called calcium carbonate, which is both prone to dissolving in acidified conditions, and more difficult for the organisms to make when fewer carbonate ions are available. This is predicted to be the case as more carbon dioxide enters the oceans. This lab demonstrates that a strong acid like vinegar (which has a pH of about 2.4 undiluted, and 2.56 in the 1:1 solution with fresh water) can significantly weaken shells and cause them to break more easily under pressure and weight.

ACTIVITY

1. Engage/Elicit

Ask the students to give examples of different species of shellfish. Answers may include clams, oysters, mussels, scallops, etc. Ask students why and where they have seen these creatures. Students' knowledge may come from eating seafood, or perhaps from having seen them in a marina or in coastal areas. Ask the students why these animals are important to the marine environment and to human beings.

2. Explore

Lay out an assemblage of the non-soaked shells. Have the students observe and identify the different species mentioned during the first part of the activity. Allow the students to handle the shells and ask them why the development of shells is advantageous to such animals. Explain that shellfish are invertebrates, meaning that instead of having an internal skeleton like humans, invertebrates produce a hard, protective covering. Mention that shellfish make their shells by combining calcium (also a major component of our bones!) with carbonate, two substances found in seawater. The product, calcium carbonate, is the same material that chalk is made out of.

After dividing students into groups of 3-4, give each group of students a control group of non-soaked shells and an experimental group of vinegar soaked shells that contain similar species, so that students can make a visual and direct comparison for each species.

Give each group two sheets of paper towel, labeled "Normal" and "Acid Washed." Ask students to lay the shells out on the paper towels in two groups according to the treatment. Make sure that the paper towels and arranged shells are close enough to one another so that the books you are using can cover all of them at once, but far enough to keep the groups visually separate.

The shells soaked in vinegar should look frail, brittle, washed out and feel less "intact" than their non-soaked counterparts. Ask the students to make predictions about which group of shells will withstand a greater amount of pressure (from the weight of the books) before they conduct the experiment. You can also ask them to guess how many books will cause shells from either group to break. Note that the books used for the control and experimental groups should be the same weight. If you do not have books with comparable weights, have students perform the experiment with the non-soaked shells first and then with the soaked shells to compare.

Have students carefully lay books on top of the two groups of shells until you hear or see shells cracking. Notice how much weight (how many books) is necessary to break the shells, and which kind of shell breaks first! See if the students can continue adding weight to the shells to break the (hint!) non-soaked shells – it's hard to do!

3. Explain

Initiate a discussion and ask students to share the results of their experiments. Have the students refer back to their original predictions – do the results support or refute their predictions?

4. Extend

Calcium carbonate is also the main ingredient in chalk. For a dramatic demonstration in real time, you can bring in a bottle of seltzer water (contained in a non-reactive glass beaker or Pyrex container) and drop the chalk in. The bubbles in the seltzer water are made of carbon dioxide, which will eat away at the chalk quickly and cause it to dissolve completely in a few minutes.

After watching this happen, explain that the same substance, carbon dioxide, is produced by burning fossil fuels and is entering the oceans, causing acidification. In the ocean, however, this process is happening at a much slower rate because ocean water (pH 8.1) is not nearly as acidic as seltzer water (pH 3.5).

5. Evaluate/ Wrap-up

Ask the students to brainstorm some possible implications of ocean acidification on shell-forming organisms, and problems that could come from weaker shells.

After establishing that shells can become brittle, fragile, and more easily breakable due to acidification, consider the connection between a strong, protective shell and a healthy organism. Discuss how a shell protects an organism from dangers such as predation, pounding surf, and the hot sun, and have the students think about the challenge of surviving these harsh conditions with a weakened shell. What does this mean for shellfish populations? How will this affect marine ecosystems, and/or areas where these organisms are usually plentiful?

6. Dive Deeper

This lesson was adapted from the NRDC's Ocean Acidification LabKit, which can be found by visiting the following web address: www.nrdc.org/oceans/acidification/files/labkit.pdf. To learn more about ocean acidification and other important issues facing the world's oceans, please visit www.namepa.net/education.

2: HARD TO BUILD

Grade Level: 6-8
Time: 45 minutes

SUMMARY:
This activity is designed to show students that a change in ocean chemistry will likely make it more difficult for calcifying organisms to form their shells by limiting the amount of available calcium carbonate ions in seawater. During the first part of the activity, students create a structure out of several interlocking types of blocks. During the second part of the activity, one type of block will be made scarce, and students will rebuild their structures. The goal for each part of the activity is to maximize the weight the structure can support.

OBJECTIVES:
Students will:
- Create two structures using blocks and maximize the quantity of weight each can support.
- Simulate the challenge faced by calcifying (shell-forming) marine organisms when carbonate ions are limited in seawater.
- See the difficulty in creating a strong structure without the use of a certain element – in this case, a type of building block.

STEM APPLICATIONS:
- **Engineering** – Students will create a structure to support the maximum possible amount of weight, and will adjust accordingly after one component is limited.
- **Science (chemistry, biology)** – The chemical concept of a "limiting reactant" is illustrated by curtailing the quantity of a type of block intended to represent carbonate ions in seawater.
- **Math** – Students calculate the weight supported by the structures they build.

NGSS ALIGNMENT:
- **Practice 1.** Asking Questions and Defining Problems
  - **6-8 –** Ask questions that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information.
- **Practice 2.** Developing and Using Models
  - **6-8 –** Develop and/or use a model to generate data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales.
- **Practice 6.** Constructing Explanations and Designing Solutions
  - **6-8 –** Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.

VOCABULARY:
Ocean Acidification – A phenomenon associated with climate change that is currently observable in the world's oceans. Seawater absorbs carbon dioxide from the atmosphere and in turn becomes more acidic. The impact on marine life is not fully understood, but a quick change in acidity could make it hard for marine organisms – especially shell-forming ones – to survive.
Calcification – The biological process of combining calcium with carbonate to create material that forms an exoskeleton or shell.
Calcium Carbonate ($CaCO_3$) – A material produced by mollusks and other shell-forming organisms through calcification. The two different forms of this compound are calcite and aragonite.
Carbonate – A compound of carbon and oxygen that is currently abundantly available in seawater, but may become limited if oceans continue to become more acidic.
Ion – A form of a chemical compound with either a positive or negative charge. Carbonate (CO_3^{2-}) is a negative ion, while calcium (Ca^{2+}) is positive – these equal and opposite charges allow them to bond.
Limiting Reactant – The component of a chemical reaction that is in the least supply and determines the amount of product produced.

MATERIALS:
- Blocks set with several distinct shapes/types. K'Nex builders sets work especially well for this activity.
- Heavy objects such as books, blocks, a weight set, etc.
- A scale (optional, to measure exactly how much weight each structure supported)

BACKGROUND:
The manner in which calcifying organisms like clams, oysters, mussels, snails, and even some species of phytoplankton will respond to ocean acidification is of particular concern. As the overall pH of ocean water continues to decrease, the resulting acidifying conditions may be corrosive to organisms' shells, which are made of sensitive calcium carbonate (see lesson 1 in this chapter, *Shells in Acid*, for a demonstration of shell corrosion in acid). However, shellfish and other marine calcifiers face yet another challenge associated with ocean acidification – the limited ability to create their shells at all! As the concentration of carbon dioxide in the atmosphere increases due to human activity, greater amounts of carbon dioxide are dissolving into the world's oceans. Carbon dioxide forms carbonic acid in seawater, which lowers the overall pH, and causes further dissociation into carbonate, bicarbonate and hydrogen ions. Excess hydrogen ions in seawater interfere with the calcification (shell-forming) process, as they are quick to bond with the carbonate ions that these organisms would otherwise use to form their shells. Limiting the concentration of bioavailable carbonate ions in seawater could have serious affects on the marine calcification process – and might negatively affect shellfish populations

worldwide. This activity demonstrates how limiting access to a key component of a structure can affect its integrity and ability to withstand outside pressure.

ACTIVITY:

1. Engage/Elicit

Ask students to consider why organisms like clams, oysters, mussels, and snails build shells. What environmental conditions do they need to withstand? Answers may include wave action (especially for those creatures like periwinkle snails or blue mussels that often live in the rocky intertidal zone – a very stressful place to survive in!), protection from desiccation (drying out), protection from predation, etc. Get the students thinking about what kinds of pressure these kinds of animals face living on the coast, and how having a strong, healthy shell helps them survive.

Now ask the students to describe what a strong shell looks like, feels like, and how it's designed. You can talk about how an organism forms it's shell – from the center, or smallest point, outward – and even show a few photographs of the various stages of a shellfish's life. Explain "calcification:" the process where shellfish take calcium and carbonate (made from carbon and oxygen atoms) from seawater and combine them to make the hard substance that forms their shell.

Visit http://www.whoi.edu/home/oceanus_images/ries/calcification.html for an illustrated overview of the effect of ocean acidification on the calcification process.

2. Explore

Before starting the building activity, discuss the students' commentary on strong, durable shell shapes and qualities and ask them to relate these to buildings. What are common shapes used in construction? Why is this so? What makes a strong building that can support itself and the weight in or on it?

After the discussion, divide the students into groups of 4-6 and provide each group with a building kit, which should consist of blocks of several different types. Give the students a time limit of about 20 minutes to design and build a structure that will support the heavy objects you have for the activity. When time is called, each group should place the heavy objects carefully on their structure in order to maximize the pressure it supports! This may mean that the structure ultimately collapses – or, you can visually evaluate how much tension the structure is under and cut the weight off at a certain point. If you are using a scale, the students can then record the weight of each item, and calculate the total weight that the structure supported before the collapsing point.

Upon completion, ask all groups to disassemble their structures entirely. Choose one type of block that is integral to construction and providing structural integrity and remove this type of block from each group. Now repeat the experiment using only the blocks that remain. The students should find it more challenging to make this structure without the use of the blocks you removed!

Each group should attempt to add the weight that had been supported by their original structure. Students should record the total weight that the new structure supports and compare this value to the total weight supported by the original structure – is it more, less, or equal?

3. Explain

After the students have obtained values for the maximum weight supported by their first and second structures, ask each group to share their data and observations. It is possible that their second structures supported less weight, were different shapes, or were less stable overall, than the first round of structures? Ask the students to compare and contrast the two structures.

Discuss the challenges faced when building the second structure when most of one useful type of block was taken away. How did that change the way they designed their structure? What was the role of this type of block in supporting the overall structure?

Now talk about the concept of resource limitation and the impact it can have on both human-made structures like buildings, and on shells made by marine organisms. Ask the students to think of the type of block that was removed as calcium, which is predicted to become more and more scarce as ocean acidification progresses. Ask them to think about what this might mean for shellfish in the future –how do the complications faced in this activity translate to those faced by shell-forming organisms? Will they be able to build shells without this necessary "building block?" If shellfish cannot create their shells, how might that impact ecosystems, and in turn, human beings?

4. Evaluate/ Wrap-up

After each group has had a chance to share their thoughts on limiting resources, check for understanding by going over the vocabulary words in context. Ask students to explain what calcium carbonate is. Mention that it is what mollusks and other shellfish make their shells out of, and that it is formed when these animals combine calcium with carbonate ions that they take from seawater.

5. Dive Deeper

Learn more about ocean acidification by visiting The National Resources Defense Council (NRDC) website at http://www.nrdc.org/oceans/acidification/. There, you can view graphic representation of this large-scale oceanic issue, and view the short film Acid Test: The Global Challenge of Ocean Acidification.

To learn more about ocean acidification and other important issues facing the world's oceans, please visit www.namepa.net/education.

3: MODEL CO_2 DISSOLVES IN SEAWATER

Grade Level: 9-12
Time: 60-75 minutes

SUMMARY:

In this interactive lesson, students will learn the specific chemical reaction that occurs when atmospheric carbon dioxide dissolves in seawater. Students will create a physical model to describe the reaction and to demonstrate how increasing levels of carbon dioxide in the world's oceans contribute to a decrease in average pH.

OBJECTIVES:

Students will:
• Use 3D materials to visually represent the change in ocean chemistry that occurs when carbon dioxide reacts with seawater.
• Describe and discuss this reaction using their model.

STEM APPLICATIONS:

• **Science (chemistry)** - Chemical reaction of carbon dioxide and seawater is illustrated.
• **Technology** - Students will perform brief research on ocean acidification on computers.
• **Engineering** - Students will use materials to create a structure.

NGSS ALIGNMENT:

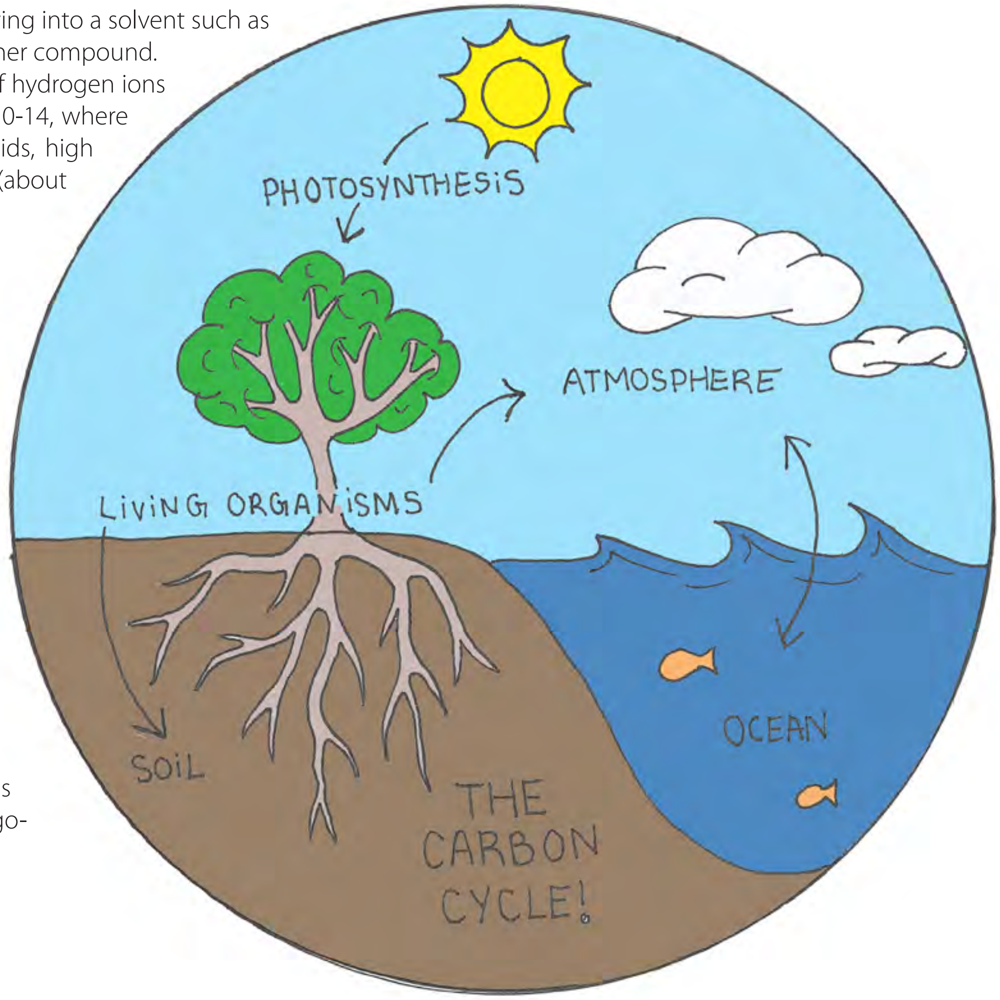
• **Practice 2.** Developing and Using Models
  • **9-12** - Develop, revise and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.
• **Practice 3**. Planning and Carrying Out Investigations
  • **9-12** – Select appropriate tools to collect, record, analyze and evaluate data.
  • **9-12** – Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled.
• **Practice 6.** Constructing Explanations and Designing Solutions
  • **9-12** – Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.
  • **9-12** – Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.
• **Practice 8. Obtaining**, Evaluating, and Communicating Information
  • **9-12** – Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.

VOCABULARY:

Ocean acidification – A phenomenon that is occurring in the world's oceans due to increasing concentrations of anthropogenic carbon dioxide in the atmosphere. Acidification occurs when carbon dioxide dissolves in seawater and dissociates into carbonic acid and other carbon species, which in turn lowers the pH. The impacts to marine life are not fully understood, however a rapid change in the average oceanic pH could make it hard for marine organisms – especially shellfish – to survive.
Air-Sea Gas Exchange – A physio-chemical process where differences in concentrations of certain gases in seawater and the atmosphere cause molecules to continually cross the boundary between the ocean's surface and the air.
Ocean Chemistry – The chemical composition of seawater and the many compounds, elements, gases, minerals and organic and particulate matter it contains.
Carbon Dioxide – CO_2 – A gas produced by burning carbon. It is naturally present in the atmosphere, but humans have altered the carbon cycle and substantially increased the atmospheric concentration of carbon dioxide, mostly by burning fossil fuels like coal, natural gas, and oil.
Carbonic Acid – H_2CO_3 –A weak acid that forms when carbon dioxide (CO_2 –) reacts with water (H_2O). It is this acid, in addition to a greater concentration of free-floating hydrogen ions, that is causing the pH of the oceans to decrease.
Carbonate – CO_3^{-2} – Carbonate is an ion with a negative charge that is the only bioavailable species of carbon in ocean water. Calcifying organisms combine carbonate with calcium to form shells.
Bicarbonate – HCO_3- – Like Carbonic Acid and Carbonate, Bicarbonate is a product of the chemical reaction between carbon dioxide and seawater.
Speciation – The chemical form or compound in which an element occurs. Carbonic Acid, Carbonate, and Bicarbonate are all "species" of carbon.
Dissolution – When a compound such as carbon dioxide sepa-

rates into individual elements by dissolving into a solvent such as ocean water, and recombines into another compound.

pH – A measure of the concentration of hydrogen ions present in a substance on a scale from 0-14, where low numbers represent very strong acids, high numbers are very strong bases, and "7" (about the pH of drinking water) is neutral.



MATERIALS:

The materials you provide for this activity are at your discretion, and might include: straws, pipe cleaners or wooden dowels, sticky tack or glue to hold models together, construction paper or wooden blocks to represent the different chemical compounds, and various other materials for decoration or labeling purposes. The models themselves may be constructed in any shape or size (and the creativity of the students should reign there!) or, alternatively, the activity may be done as a 2D diagram on a poster-board or a piece of paper.

You will need distinct materials/supplies to represent each of the following categories:

- Carbon dioxide molecules
- Carbonate ions
- Bicarbonate ions
- Hydrogen ions
- Carbonic Acid
- The ocean
- The atmosphere

BACKGROUND:

The concentration of carbon dioxide in the atmosphere is increasing rapidly, generated from human activities that require burning fossil fuels. While some of theses carbon dioxide emissions remain in the atmosphere, about 1/3 are absorbed by the oceans. This is equivalent to about 22 million tons per day!

The dissolution of carbon dioxide in seawater produces carbonic acid – a naturally occurring substance that has remained in balance with other products like carbonate, bicarbonate and hydrogen ions. In the last century and a half, however, humans have added an immense amount of carbon dioxide to the atmosphere, disrupting the carbon cycle and causing a 0.1 unit drop in the average pH of the world's oceans. If this trend of ocean acidification continues, marine species may face extraordinary challenges and conditions to which there are unable to adapt. Since this phenomenon was identified in 2005, ocean chemists have pinpointed the specific chemical processes that occur when carbon dioxide dissolves in seawater. In this activity, students will recreate this process with a physical model that shows just how our oceans are acidifying.

ACTIVITY:

1. Engage/Elicit

To begin this activity, it is helpful to have the students perform research to start to understand the process by which carbon dioxide enters the oceans. Divide the students into groups of 3-4 and ask them to take notes on articles they find on "carbon dioxide in ocean water." You can suggest they do a Google search for these terms, or direct them to the following web pages, which illustrate this process clearly:

a) http://www.pmel.noaa.gov/CO2/story/Ocean+Carbon+Uptake
b) http://earthobservatory.nasa.gov/Features/OceanCarbon/
c) http://ocean.nationalgeographic.com/ocean/critical-issues-ocean-acidification/

After 15-20 minutes of research and note taking, ask the students to share any interesting facts they have found about climate change and/or ocean chemistry. Incorporate their input and information to recreate the chart (Figure 1) at the end of this lesson as a drawing on a whiteboard, or print the chart out to display the process of carbon dioxide dissolving in seawater.

2. Explore

After posting the diagram of carbon dioxide dissolving in seawater clearly so the students can use it for reference, direct the groups of students to the materials you have provided for modeling. Ask each group to use the diagram to build a model that represents ocean acidification, or in other words, the dissolution and speciation of carbon in seawater. Be sure to ask students to label all parts of the model clearly.

3. Explain

Lead a discussion on the process that the students have now modeled. Students should understand that as carbonic acid accumulates, it contributes to the lowering of the overall pH value of ocean water – the fact that carbonic acid is an acid makes this rather intuitive. The resulting excess pool of hydrogen ions also contributes to the lowering pH, as the pH of any substance is a measure of the total number of H+ ions in a given solution. Mention that the pH scale ranges from 0 to 14, with neutral being a pH value of 7. Acids, which have pH values below neutral, have increasingly higher concentrations of H+ ions as the pH value decreases– 10 times more, in fact, at each interval. That is, a substance with a pH of 1 has 10 times more H+ ions as a substance with a pH of 2, 100 times more H+ ions as a substance with a pH of 3, 1,000 times more H+ ions than a substance with a pH of 4, and so on! Therefore, a separation of just one number on the pH scale represents a huge difference in the overall acidity of the substance.

Explain that the average pH of seawater over the past 300 million years has been about 8.2, which is slightly basic. Since the industrial revolution, the pH of seawater has dropped about 0.1 units, which is a 25% increase in acidity in just 150 years! In the next century, pH is projected to decrease up to another 0.5 units – which could have grave consequences on marine life that may not be able to adapt to these rapidly acidifying conditions.

4. Evaluate/ Wrap-up

After the students have finished constructing their models, ask each group to present to the class on what they have made. Check their understanding by asking questions about each of the different chemical compounds – how they are formed, and in what order. Ask them to describe how this chemical reaction contributes to lower pH values and acidification.

5. Dive Deeper

The National Oceanic and Atmospheric Administration (NOAA) Ocean Acidification Program offers an up-to-date and comprehensive scientific analysis of this global marine issue, and with great resources to learn more and share knowledge. Access online at http://oceanacidification.noaa.gov/.

To learn more about ocean acidification and other important issues facing the world's oceans, please visit www.namepa.net/education.

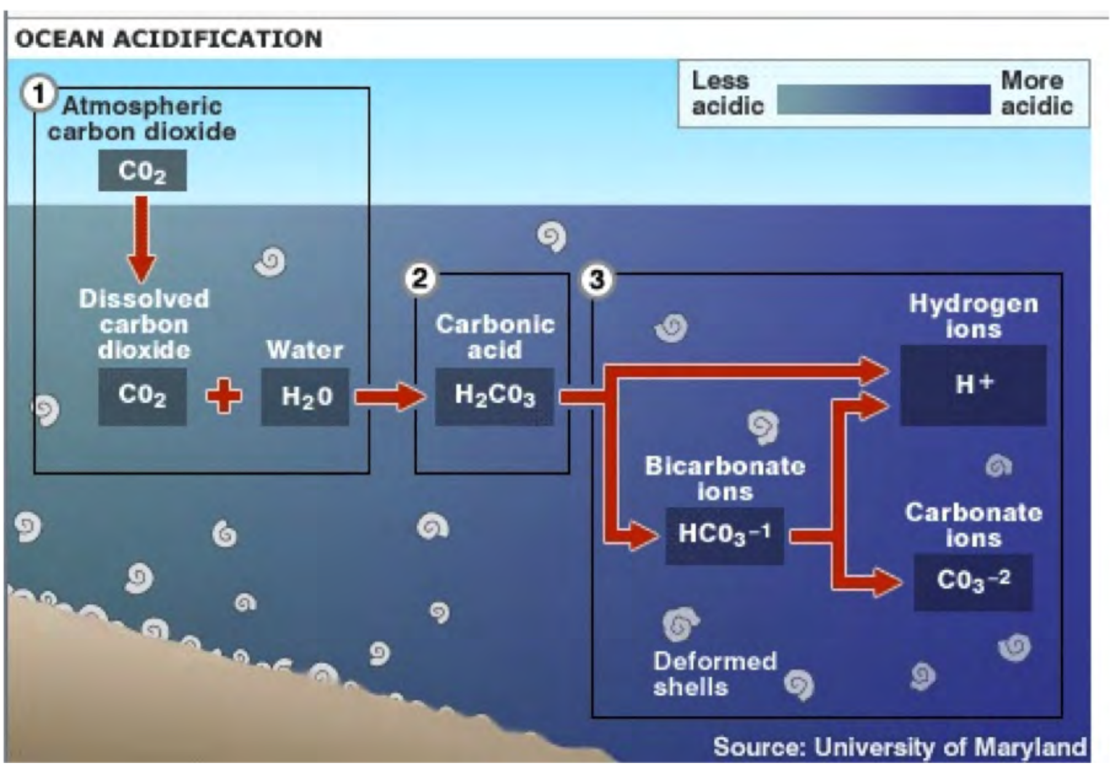


Figure 1. Ocean acidification

Ocean Exploration

4: SCAVENGER HUNT

Grade Level: K-5
Time: 45-60 minutes

SUMMARY:

This immersive lesson allows students to explore their local coastal area on a scavenger hunt for items commonly found at the seashore. This activity is a great way to introduce students to the flora and fauna that can be found along the coast, and to help them interpret our interaction with it as coastal citizens. The hunt is on!

OBJECTIVES:

Students will:

- Work in teams to explore their local beach or coastal zone in order to find items that match general descriptions on a list.
- Identify organisms or objects they find and learn species' names, as well as the terminology for different zones on the beach.

STEM APPLICATIONS:

- **Science (ecology, geology)** - Students will investigate different species of animals and plants found along the seashore/coastal zone, and will become familiar with the coastal landscape as they explore.
- **Technology** - Students may use an iPad or camera to take photos of the organisms or objects they find.

NGSS ALIGNMENT:

- **Practice 3**. Planning and Carrying Out Investigations
  - **K-2** – Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence to answer a question.
  - **K-2** – Make observations (firsthand or from media) and/or measurements to collect data that can be used to make comparisons.
  - **3-5** – Evaluate appropriate methods and/or tools for collecting data.
- **Practice 8.** Obtaining, Evaluating and Communicating Information
  - **K-2** – Communicate information or design ideas and/or solutions with others in oral and/or written forms using models, drawings, writing or numbers that provide detail about scientific ideas, practices, and/or design ideas.
  - **3-5** – Communicate scientific and/or technical information orally and/or in written formats, including various forms of media and may include tables, diagrams and charts.

VOCABULARY:

Intertidal Zone – The area of the seashore that is above the water at low tide and below the water at high tide. It is a difficult environment for marine organisms to survive in, and these animals (like mussels, snails, and other shelled creatures) usually have adaptations that protect them from dangers such as desiccation and predation.
Sublittoral Zone – The part of the ocean that is close to shore and is shallow enough for sunlight to reach the ocean floor.
Coastal Zone – The area at which land and sea meet and interact. This area may be a beach, a cliff's edge, a protected area (as in a bay) or out in the open (as an island, surrounded by water).
Sand – The material that most often covers the ground in the coastal zone, it is produced by wave action grinding against the land along the coast. There are many different types of sand, usually identified by the size of the grain.
Organism – Any living thing, which can respond to change in its environment, reproduce, grow and develop.

MATERIALS:

- Scavenger hunt sheet (attached to this guide, items/descriptions can be changed to fit your geographic location)
- One or more rulers per group
- Pens or pencils for each student
- iPad or camera (optional, to take pictures of the things you find!)
- Timer (optional)
- Reusable bag and gloves (optional, for bottle caps/litter)
- Clipboards

BACKGROUND

Getting out of the classroom and heading to the beach is a great way to learn about the ocean and the coast! Many of us are fortunate enough to live in or near coastal communities, and in this lesson students are encouraged to explore these natural areas with a

scientist's eye for detail.

ACTIVITY:

1. Engage/Elicit

Begin this activity by asking students to describe their local beach. What kinds of things are there to do and see? Ask them about the different kinds of creatures they have found while at the beach, which may include shellfish, birds, seaweed, jellyfish – any of many common coastal creatures. Explain to the students that they will be participating in a scavenger hunt.

2. Explore

Before you leave, divide the students into two or more teams, depending on class size. Give each student a copy of the Scavenger Hunt sheet and ensure that everyone has a writing utensil and clipboard so they can record the items they find. If students will be collecting trash, make sure they have gloves and each team has a reusable bag. Each team will also need a ruler and an iPad/camera (optional).

Upon arriving at the coastal location, explain the boundaries for the hunt, which may be that the first group complete the list wins, or that the team with most items in a given amount of time will be the winner. Every student will need to record the description and location of each item their team finds. Students should also be informed that there is no need to pick up or move any of the objects (with the exception of the bottle caps/litter items). Remember: observe, don't disturb!

After handing out all of the supplies, say "GO," and the hunt is on!

3. Evaluate/ Wrap-up

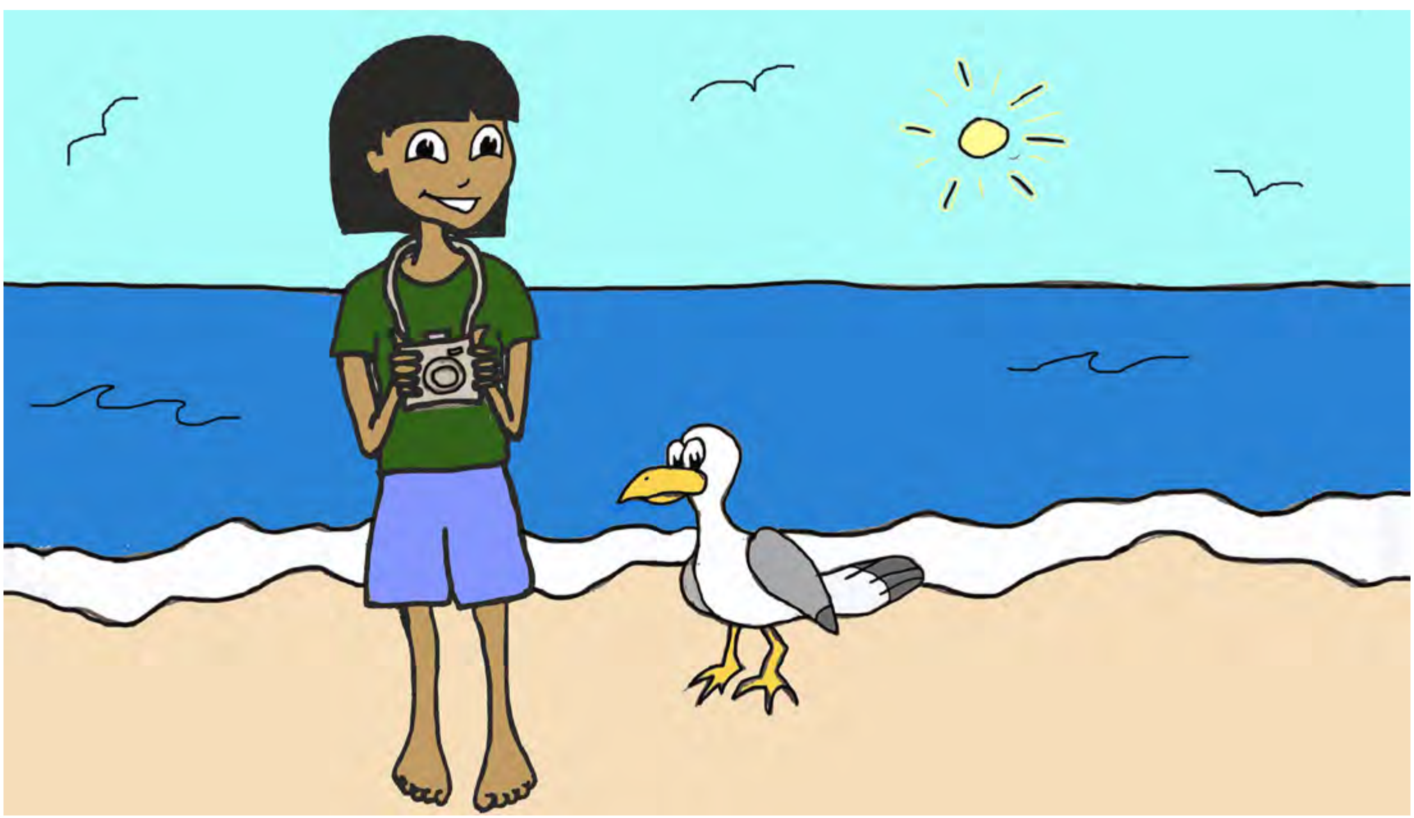
After the scavenger hunt is over, ask each group to get together to present their findings to the rest of the class. Students can read their Scavenger Hunt sheets, show pictures, or both! The important thing here is that the students are able to explain why they chose each item to fit the corresponding description, and describe where they found it using terminology on the vocabulary list above. The broad nature of the descriptions allows for many different interpretations – notice if groups tended to choose similar or different items for each description.

Have students share any thoughts and discoveries made during the activity. This is a great opportunity to talk to students about these new and interesting finds – perhaps a species they've never heard of, or an important organism in a coastal ecosystem.

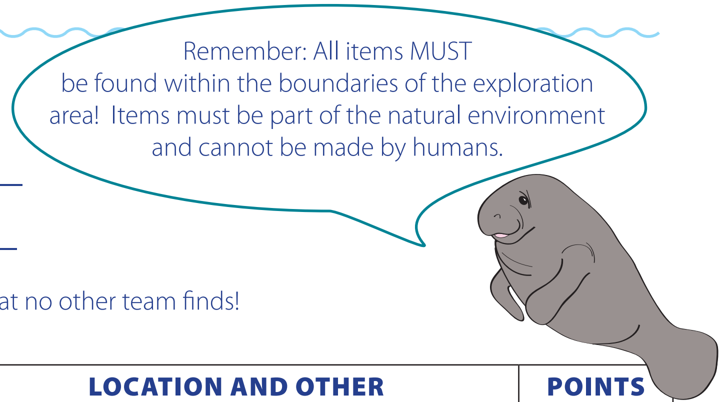
4. Dive Deeper

To find out how you and your students can get involved in protecting your local coastlines and beaches, consider participating in International Coastal Cleanup Day! Visit the Ocean Conservancy's website at www.oceanconservancy.org/our-work/international-coastal-cleanup/ to find out how you can get involved. If you're a resident of California, visit www.coastal.ca.gov/publiced/ccd/ccd.html to see where in California you can volunteer to pick up trash and keep your beaches free from debris!

For more fun activities that get students interested in ocean exploration, visit www.namepa.net/education.



SCAVENGER HUNT



NAME:____

TEAM:____

Scoring: 1 point for each item you find, +1 bonus point for each item that no other team finds!

DESCRIPTION	ITEM	LOCATION AND OTHER OBSERVATIONS	POINTS
A good hiding spot for marine creatures			
Something between 1 cm and 2.5 cm long			
A shell with 2 parts			
An ocean animal buried in the sand			
A leaf of any color EXCEPT green			
A bottle cap*			
A seed			
A plant growing on another plant			
Something blue			
A feather			
A multicolored shell			
A bird walking on the beach			
Something orange			
A rock with an interesting shape			
Something pink			
Something less than 1mm long			
Your team doing a human pyramid			5 POINTS!
TOTAL:			

*THIS IS THE EXCEPTION TO THE DON'T-PICK-IT-UP RULE! GRAB AND STORE BOTTLE CAPS IN YOUR TEAM'S TRASH BAG, WE'LL PUT THEM IN THE RIGHT PLACE WHEN WE COME BACK!

5: BUILD YOUR OWN UNDERWATER EXPLORATION VEHICLE

Grade Level: 6-8
Time: 45-60 minutes

SUMMARY:

This lesson provides a hands-on way to introduce students to the challenges of underwater research. In groups, students will design and build underwater exploration vehicles from common household/craft materials, and then compete to see which group can successfully retrieve "undersea samples" from a model ocean (2 L bottle full of water) in the fastest time. In doing so, students will learn which shapes, sizes, and features work best to carry out this underwater task – and which don't! This lesson is an introduction to robotic technology in oceanography and to the applications that these vehicles have to biologists, chemists, geologists, and physical oceanographers.

OBJECTIVES:

Students will:

• Design and build their own underwater exploration vehicle using household materials.
• Identify the challenges encountered when designing a vehicle for underwater exploration.
• Determine what shapes and designs are optimal versus those that need alteration.

STEM APPLICATIONS:

• **Science (oceanography)** – Students learn about the tools oceanographers use to conduct scientific research.
• **Technology** – Designing tools to complete a specific task will show students how technology can be used to achieve goals.
• **Engineering** – Students will use critical thinking and structural analysis skills to effectively design a tool ("vehicle") that is capable of retrieving objects from a model ocean.

NGSS ALIGNMENT:

• **Practice 1.** Asking Questions and Defining Problems
  • **6-8 –** Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.
• **Practice 3.** Planning and Carrying Out Investigations
  • **6-8 –** Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation.
  • **6-8 –** Evaluate the accuracy of various methods for collecting data.
• **Practice 6.** Constructing Explanations and Designing Solutions
  • **6-8 –** Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints.
  • **6-8 –** Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising and re-testing.

VOCABULARY:

Underwater Exploration Vehicle (UEV) – Any of several types of vehicles used to conduct research or carry out tasks underwater.
Human Occupied Vehicle (HOV) – A vehicle used for underwater exploration that can hold one or more people inside of it.
Remotely Operated Vehicle (ROV) – Another type of vehicle used by scientists to study the ocean. An ROV is attached by a cable to a boat floating on the surface, and can be controlled from there.
Automated Underwater Vehicle (AUV) – A third, more advanced type of underwater exploration vehicle that can be programmed or controlled, but does not need to be attached to a boat or external source of power in order to operate.
Marine Engineer – A person who designs equipment or machinery, including exploration vehicles, for use in working with or studying the ocean.
Hydrodynamic – Designed to be able to move through water quickly and efficiently, without much resistance.

MATERIALS:

• 2 L bottle with the top cut off (use masking tape around the rim to protect students from sharp plastic edges)
• 1.7 L water
• Duct tape
• Rubber cement
• Scissors
• "Deep-Sea Samples" – these can include beads, paper clips, dried beans, pennies, crumpled pieces of paper, erasers, or any other (relatively) waterproof objects. These can either sink or float – it works best to use a variety of shapes and sizes.
• Tool-making supplies – pipe cleaners, string, small paper cups, sticky tack, rubber bands, washers, film canisters, electrical tape, popsicle sticks, and/or any other items easily acquired that can be used to build underwater exploration vehicles!

BACKGROUND:

Believe it or not, 50% of all species on earth live in the ocean, and oceans cover about 70% of our planet, but only about 5% has been explored so far!

The use of robotic technology in oceanography has helped scientists access areas of the ocean that would otherwise be impossible to reach. A variety of sensors can be added to such vehicles that measure the concentration of certain chemical compounds, salinity, temperature, water pressure, light levels, and the presence of microscopic life. Unlike humans, robots can dive deep, stay underwater for extended periods of time, endure extreme temperatures and harsh conditions, and don't get seasick!

Coming up with designs for these underwater exploration vehicles and testing how well they work for underwater research is a significant challenge faced by marine engineers. Scientists like marine biologists, chemists, geologists, and physical oceanographers use robotic technology to collect samples, visually explore ocean environments, and track current speed and direction, and there are many more applications for this kind of technology in marine science. In this lesson, students will be able to design and test underwater exploration vehicles, and discover which designs are best for the collection of "undersea samples" from a model ocean!

ACTIVITY:

1. Engage/Elicit

To begin this activity, ask students, "Why do we study the oceans?" Answers may include: to discover new species and forms of life, to uncover geologic time records that help us learn about earth's history, that shipwrecks can be found on the ocean floor and contain important anthropological artifacts, or to find new and unknown biological and chemical environments, such as hydrothermal vents. Of course, answers can go beyond this! Encourage students to think about interesting facts they've learned about the oceans, and how those kinds of discoveries were made.

Now, ask the students to think about some of the major challenges of ocean exploration – what makes studying underwater organisms or phenomena difficult for us as human beings? How can we overcome these challenges? The idea is to get the students thinking about how humans are not well suited for oceanic conditions. Our lungs are not designed to breathe water or withstand pressure that increases with ocean depth, our bodies are not fit for the darkness or extreme temperatures at the bottom of the ocean or at hotspots like hydrothermal vents, etc.

You can also ask the students to describe what adaptations a human being would need in order to be able to effectively study in these challenging environments. At this point, you can bring up the utility of robotic technology in solving some of these problems, and address the shortfalls of studying unaided. Robots enable us to access places on earth and in the oceans that we would otherwise be unable to get to!

2. Explore

Divide the students up into groups of 3-4 and give each group a model ocean – a 2 L bottle filled about ¾ of the way with water. Place your deep-sea samples in the model ocean before starting the activity. It is ok if not all objects sink, as it will be a challenge to pick up the floating ones too!

Provide the tool-making supplies and allow students to come up in groups to take those that they find necessary to build their vehicles. Allow students time to discuss their design ideas, given the materials they have, and then encourage them to start building!

For the first part of this activity, the students will test out their respective designs in their model oceans and attempt to recover all of the deep-sea samples using the tools they have built. The rules are as follows: no part of the students' bodies may go under the water at any time, and the model ocean must stay upright. When each group has successfully collected all (or most) of their samples, move on to the second part of the activity: the Collection Competition!

The Collection Competition: for this activity, each group will get to use their one best design to retrieve the samples again, but this time the objective is to collect them all (without damaging them) before any other group does. You, as the instructor, may decide to permit the use of multiple tools, but limiting the students to one tool causes them to consider how to innovate for multiple different shapes and sizes of samples. Dump all of the samples back in each of the model oceans, and when all groups have selected their best design and are ready to go, start the competition! Whichever group can show that their samples are all collected and undamaged wins!

3. Explain

During the activity, ask students what some advantages and disadvantages are to using robotic technology as part of scientific investigations. How do you think explorers decide which tools to use on a given expedition?

You can also discuss what the different kinds of samples you provided might represent in the actual ocean. For example, a round bead that sinks to the ocean floor could bear resemblance to a rock or artifact from a shipwreck. Explore these comparisons and discuss which methods might work to retrieve these objects.

4. Evaluate/ Wrap-up

To Wrap-up this activity, discuss the questions below. As the students answer, have them provide evidence for their opinions based on their experience with designing and testing their vehicles. Go around the room and encourage each group to share their designs with the class, especially when talking about the size and shape and other design features that worked well to complete the task.

· What was the easiest part of this activity? What was the hardest part?

· What size and shape of AUV was the best at retrieving the samples? Why do you think this is?

· What materials were best to work with? Which weren't so good?

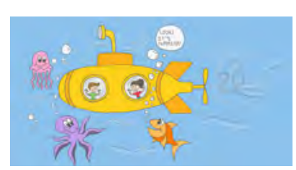
· Which samples were most difficult to pick up? How did you solve this problem?

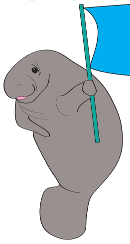
5. Dive Deeper

This lesson is adapted from a lesson published in the Immersion Presents: Ocean Exploration lesson packet created by the Sea Research Foundation.

Ever wonder what the vehicle that discovered the Titanic looked like or how it operated? Want to see how scientists aboard real-life HOVs conduct research and make important oceanic discoveries? Check out Woods Hole Oceanographic Institution and the famous HOV, Alvin, at www.whoi.edu/main/hov-alvin. To view a more modern design and breakthrough technology, check out the Deepsea Challenger, the one-person HOV donated by James Cameron after he dove into the deepest known part of the ocean, the Marianas Trench! Visit www.whoi.edu/main/deepseachallenger.

For more activities and information on ocean exploration please visit www.namepa.net/education.





6: WAVES AND LIGHT IN THE OCEAN

Grade Level: 9-12
Time: 30-45 min

SUMMARY:

In this activity, students will complete a short research assignment on the behavior of light in the ocean, and use this information to make a visual representation of the different light zones in the ocean, and learn which wavelengths of light are able to penetrate to each depth.

OBJECTIVE(S):

Students will:
• Identify the characteristics of the different zones of light in the ocean.
• Understand the relationship between water depth and light zones.
• Model and discuss the behavior of sunlight in the ocean and the degree of penetration of different wavelengths.

STEM APPLICATIONS:

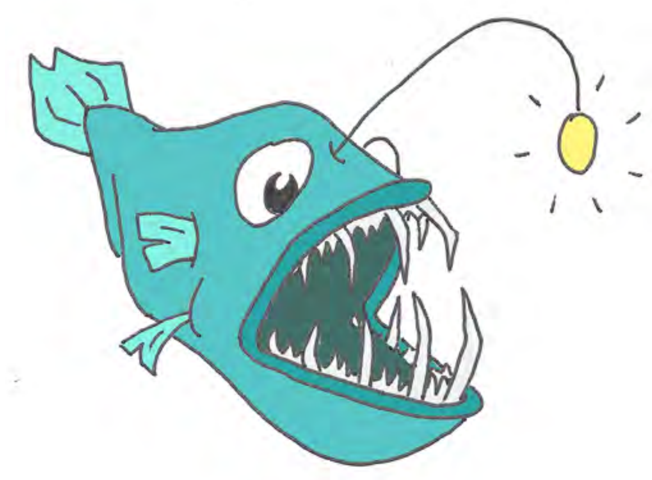
• **Science (physics, biology)** - Students will understand the laws of physics that govern the behavior of light in water, and how it differs from its behavior on land. Light is a major determiner of the assemblage of animals that can live in each zone of the ocean, and students will study this biological relationship.
• **Technology** - Students will conduct research on the interaction of light in the ocean using a computer.
• **Engineering** - Students will use their knowledge of light zones to construct a model of color-depth penetration in the ocean.

NGSS ALIGNMENT:

• **Practice 2.** Developing and Using Models
  • **9-12 –** Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.
• **Practice 4.** Analyzing and Interpreting Data
  • **9-12 –** Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations.
• **Practice 8.** Obtaining, Evaluating and Communicating Information
  • **9-12 –** Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.
  • **9-12 –** Gather, read and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.
  • **9-12 –** Communicate scientific and/or technical information or ideas (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically).

VOCABULARY:

Optical Oceanography – The study of how light behaves in the ocean.
Wavelength – A measure of the distance between two crests of a wave. Different colors in the color spectrum have different wavelengths – violet is the shortest, and red is the longest.
Amplitude – The maximum "height" of a wave, or the distance it travels away from the midline in either direction.
Spectrum – All of the colors that make up visible light.
Frequency –The number of wavelengths that pass a certain point in a given period of time. The unit of measure is Hertz (Hz), which reports wavelengths per second.
Speed of Light - = wavelength x frequency.
Photic or Epipelagic Zone – The upper layer of water on the surface of the ocean in which light penetrates sufficiently to allow photosynthesis.
Dysphotic or Mesopelagic Zone – Also known as the "twilight zone," this layer of the ocean is in between the photic and the aphotic zone. Only certain colors on the spectrum penetrate to this depth, and light is too limited for photosynthesis to occur.
Aphotic or Bathypelagic Zone – The bottom-most layer of the ocean, in which there is no light at all. About 90% of the ocean is in this completely dark zone!



MATERIALS:

- Access to computers or textbooks on physical oceanography
- Poster board
- Glue
- Colored construction paper (red, orange, yellow, green, blue, navy blue, violet)
- Markers

BACKGROUND:

Light travels in waves at the fastest known speed in the physical universe. What appears to us as white light is actually light made up of many different colors, or wavelengths, which is the reason why we see the world in the many colors that we do. These waves are imperceptible to us, but if visible, we would notice that there are many similarities between light waves and physical waves in the ocean. In fact, many of the same measurements are used to describe the size, shape, and speed of waves for light and waves in the ocean, including wavelength and frequency.

The degree and depth to which sunlight penetrates in the ocean determines the extent of primary productivity and divides the ocean into distinct zones of life. When sunlight hits the water, about 5% is reflected back into the atmosphere, while the other 95% gets absorbed. Plankton and photosynthetic organisms live exclusively in the photic zone, the uppermost layer of the ocean where sunlight is available. These creatures absorb the usable light to produce energy, and in turn sustain all life in the ocean through the food web! As you travel further into the ocean's depths, light slowly disappears – color by color. The first color to vanish is ultraviolet, followed by red (at the extent of the photic zone), then yellow, green, and finally blue before the ocean fades into darkness.

ACTIVITY:

1. Engage/Elicit

Begin this activity with a discussion on the behavior of light. How and why do we see colors as they are? A blue shirt, for an example, is blue because it absorbs all colors with the exception of blue. Instead, it reflects it. The wavelength reflected is the color that our eyes perceive. This is true for all objects, which absorb or reflect certain parts of the spectrum of light. The color of an object is based on the wavelength of light that is reflected, not absorbed. This explains why black objects become much warmer than white objects when in the sun – black absorbs all of the colors while white reflects them.

Review the color spectrum and use the provided diagram (Fig. 1) of the different wavelengths of colored light. Go over the vocabulary words in this section to help students describe how waves are measured including: wavelength, amplitude, spectrum and frequency. Help students visualize this concept by drawing or printing a labeled wave diagram and/or color spectrum. Refer to Figures 1 and 2 for this activity.

2. Explore

Allow the students about 20 minutes to research the interaction of light and the ocean in groups. Ask the students to take notes on what they find and direct them to the following informative websites:

- www.marinebio.org/oceans/light-and-color.asp
- www.oceanexplorer.noaa.gov/edu/curriculum/section5.pdf
- www.oceanexplorer.noaa.gov/facts/light-distributed.html
- www.oceana.org/en/explore/marine-science/light-and-sound

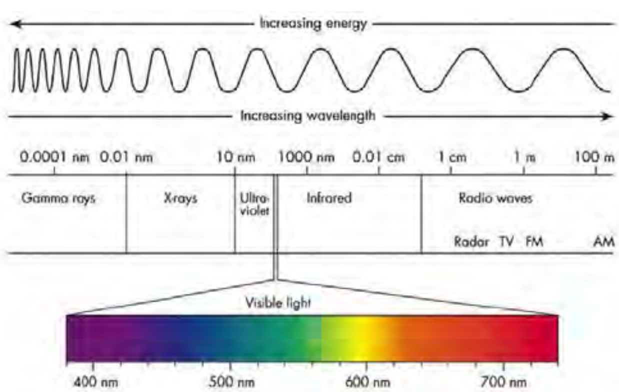


Figure 1. Wave length of increasing light

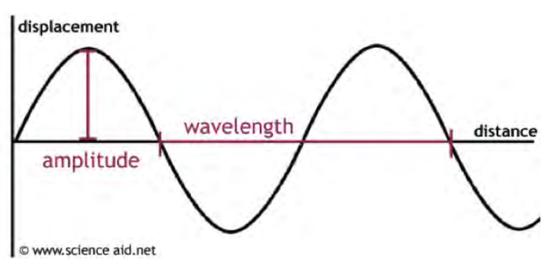


Figure 2. How waves are measured

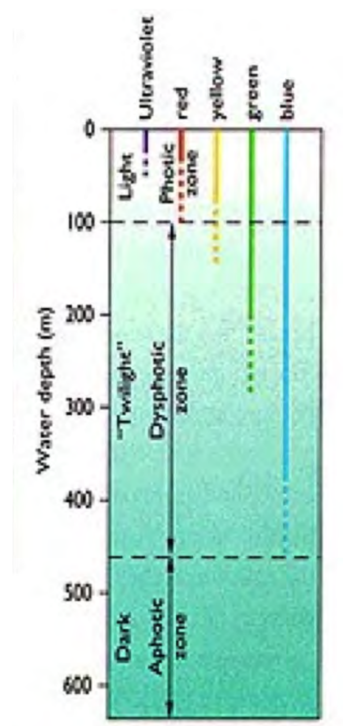
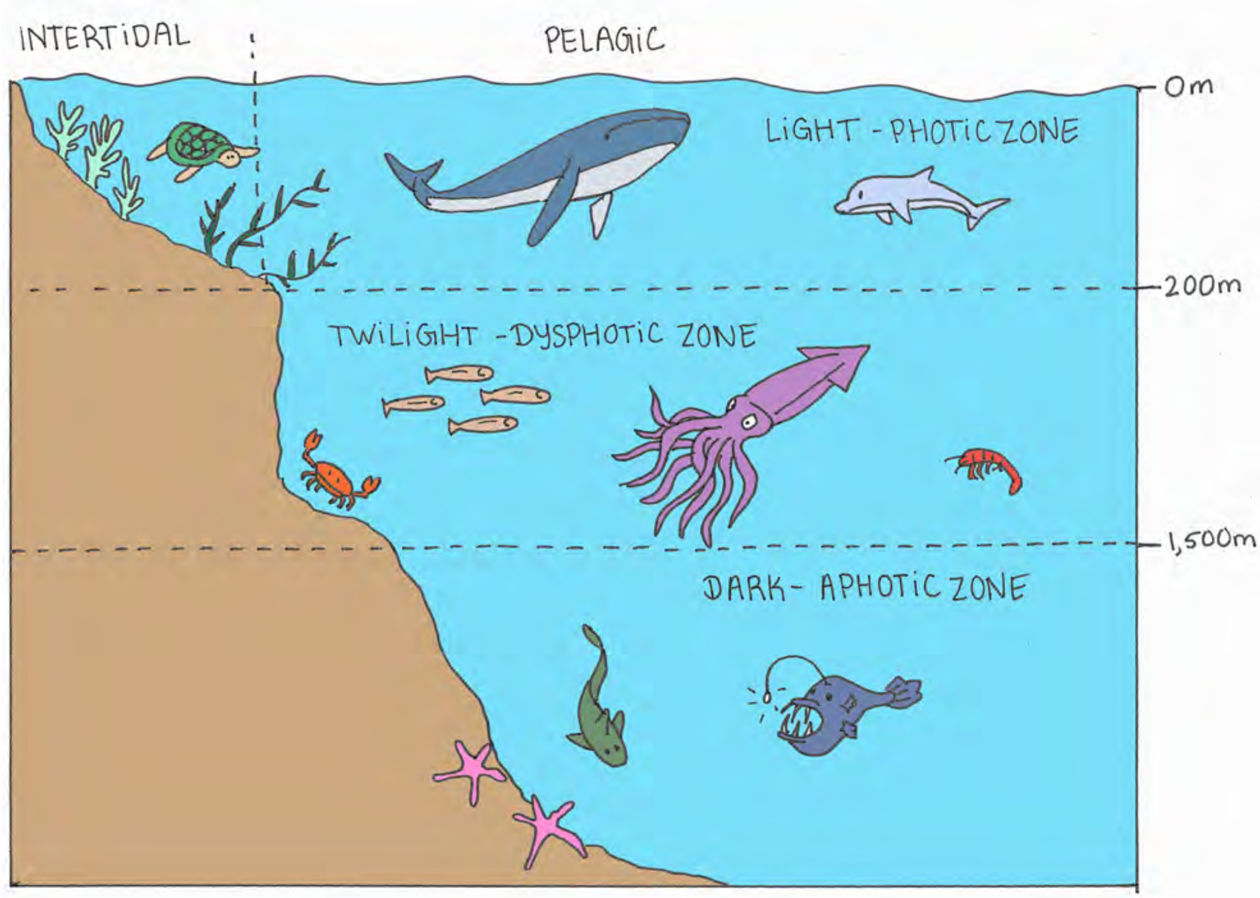


Figure 3. Lightzones

Figure 1 SOURCE: Fordham University; Figure 3 SOURCE: marinebio.org



After the students gather information, ask them to use their notes to create a poster of the light zones in the ocean using colored construction paper and glue. Make sure the students include the different wavelengths of light and their respective depths.

Creativity should be encouraged during this process! For example, the depth of the photic zone, is highly variable. In productive, coastal waters, it may only be a few meters deep, but in the open ocean (which can be devoid of planktonic life), light could penetrate all the way down to 150 meters. See Figure 3 for a reference – this is roughly the result that students should replicate. This image can be found at one of the links above, on www.marinebio.org.

Ask the students to label everything clearly, including the three zones of light/life (Photic/Epipelagic, Dysphotic/Mesopelagic and Aphotic/Benthopelagic) and use the respective color of paper to show approximately how deep in the water column each wavelength of light will travel.

3. Explain

Discuss the impact of colored light and sunlight penetration to life in the world's oceans. Ask the students why ultraviolet, red, and yellow light get absorbed mostly in the photic zone, while green and blue continue to penetrate in the water column.

The answer is that chlorophyll, the sunlight-capturing compound produced by all plants (including phytoplankton) is green! Because of what we know about light absorption and reflection, we can infer that plankton cannot absorb the color green, and therefore it gets reflected from their bodies and travels deeper into the sea. They can, however, absorb contrasting colors like red, ultraviolet, and yellow (to some extent) and use this part of the color spectrum to make energy.

4. Evaluate/ Wrap-up

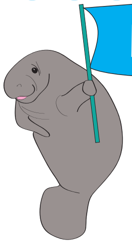
After each group has finished creating their diagram of light in the oceans, ask the students to present what they have created. Check for understanding by ensuring that all parts of the diagrams, including the ocean light and biological zones, are labeled, and that the colors are in the right order and travel to the right depth. Ask students to employ the vocabulary words in this section when they are talking about their diagrams, particularly when they describe how light moves and is used by life in the ocean.

5. Dive Deeper

Take a dive 11,000m down into the depths of an ocean trench at www.bbc.com/news/science-environment-17013285. See how the pressure and light level changes with depth, and learn about why we do science in these hard-to-reach locations on earth.

For more information on ocean exploration, please visit www.namepa.net/education.

Marine Industry



7: READ THE SKIES: CLOUDS AND WEATHER AT SEA

Grade Level: K-5
Time: 30-45 min

SUMMARY:

In this lesson, students will learn how to identify different types of clouds, and make a model of each type using cotton balls on a poster board. Students will learn how recognizing cloud types can help them make predictions about the short-term weather, and how this ability is useful to mariners who must be able to make decisions about safety based on environmental observations. Students will then use the charts/posters they have made to identify cloud types outside in the sky!

OBJECTIVES:

Students will:

• Learn the names of different types of clouds and be able to recognize them by sight (in pictures and/or in the sky).

• Recognize these types of clouds will help students make predictions about the weather.

• Understand how being able to gather information about the weather through environmental observation is important to maintaining safety at sea.

STEM APPLICATIONS:

• **Science (meteorology)** - Students are introduced to the concept of using environmental clues to predict the weather, and specifically to the ways that mariners have traditionally used clouds to predict impending weather patterns.

• **Engineering** - Students will create models of different types of clouds.

NGSS ALIGNMENT:

• **Practice 2.** Developing and Using Models
  - **K-2 –** Distinguish between a model and the actual object, process and/or events the model represents.
  - **K-2 –** Develop and/or use a model to represent amounts, relationships, relative scales (bigger, smaller), and/or patterns in the natural and designed world(s).
  - **3-5 –** Develop and/or use models to describe and/or predict phenomena.

• **Practice 3.** Planning and Carrying Out Investigations
  - **K-2 –** Evaluate different ways of observing and/or measuring a phenomenon to determine which way can answer a question.
  - **K-2 –** Make observations (firsthand or from media) and/or measurements of a proposed object or tool or solution to determine if it solves a problem or meets a goal.
  - **3-5 –** Evaluate appropriate methods and/or tools for collecting data.

• **Practice 4.** Analyzing and Interpreting Data
  - **K-2 –** Record information (observations, thoughts, and ideas).
  - **K-2 –** Use observations (firsthand or from media) to describe patterns and/or relationships in the natural and designed world(s) in order to answer scientific questions and solve problems.
  - **3-5 –** Compare and contrast data collected by different groups in order to discuss similarities and differences in their findings.
  - **3-5 -** Analyze data to refine a problem statement or the design of a proposed object, tool or process.

VOCABULARY:

Stratus – Stratus clouds are flat and horizontal.
Cumulus – Cumulus clouds are puffy and white, like cotton balls.
Altostratus or Altocumulus– Clouds with the prefix "alto-" hang in the middle of the sky, not too high up or low down. Altostratus clouds look flat, and altocumulus clouds look puffy.
Cirrus – Cirrus clouds are the highest in the sky, and are usually thin, wispy and streaky.
"Nimbo-" or "-nimbus" – When the prefix "nimbo-" or the suffix "-nimbus" is used to describe a cloud, it means "rain cloud." A cumulonimbus cloud is a very long, tall, "puffy" cloud that means thunderstorms are on the way.

MATERIALS:

• Construction paper or poster board
• Cotton balls
• Elmer's glue
• Markers
• Cloud Chart (see Figure 1)

BACKGROUND:

Long before humans had modern technology to make precise measurements, people had to rely on their eyes and ears to make predictions about the weather. Sailors in particular had be very observant and become experts at weather prediction. If storms were on the way, it was wise to stay in a safe harbor until they passed. One way to predict short-term weather is to "read" the sky – more specifically, the clouds in it! Clouds form when moisture in the atmosphere evaporates from land and the oceans into the sky, condenses there, and then falls down toward earth again as rain, snow, or other precipitation. This is called the water cycle. There are many different types of clouds that form based on different temperature, wind and environmental conditions, and knowing how to "read" these differences can help to predict what kind of weather is likely on the way.

ACTIVITY:

1. Engage/Elicit

Begin this activity by asking students to tell you what they usually associate with cloudy skies. Is it rain? Snow? Fog? Ask them to describe the cloudy days they can remember, and if there are different conditions that exist. For example, you can talk about the difference between a sunny day with just a few clouds in a blue sky, and a gray, overcast day where the clouds cover most of the sky.

Ask the students why it might be important to be able to "read" the clouds to predict coming weather conditions. How would knowing what to expect from the weather help to keep sailors safe as they travel over the oceans?

2. Explore

During this part of the activity, students will be making their own cloud charts to learn about and identify the basic differences between types of clouds. Each student may use the materials to make their own individual cloud chart, or you may choose to divide the class up in pairs or groups.

Before students begin working on the charts, share some information about different cloud formations with the students. Visit http://eo.ucar.edu/webweather/cloud3.html for a great, age-appropriate overview of the basic types of clouds. Refer to Figure 1 at the end of this chapter for a visual representation of the named cloud types.

After a discussion about the different types of clouds and what they might indicate in terms of coming weather, allow the students to make their own cloud charts using the cotton balls and construction paper or poster board. Have the students glue the cotton balls in the appropriate shapes and "densities" – which can be altered by stretching out the cotton balls before gluing them, or gluing many close together – and help them place the clouds in the general vicinity that they would be found in the sky (high, mid-level, low). Help students label each type of cloud so they can be used to identify real clouds outside later.

3. Explain

After all students/groups have finished creating their cloud charts, bring the class outside to try to classify some real-life clouds! You can gather in a safe parking lot or lay down in the grass to get a good view of the clouds that are out that day. Using their cloud charts, ask students to make their best guesses about what kinds of clouds are in the sky, and to predict what kind of weather they should expect in the coming days.

4. Evaluate/ Wrap-up

After the students have had enough time to identify and talk about what kinds of clouds are in the sky outside, steer the discussion back to how they might use this information if they were sailors on a voyage. You can ask, based on what kind of weather might be coming from your cloud observations, would it be a good idea to set sail today? If not, what kinds of clouds would you like to see before you would feel safe leaving the harbor?

5. Dive Deeper

To learn more about weather, the factors that interact to produce it, and the means by which we can predict it, visit the NOAA National Weather Service webpage at www.weather.gov/.

Learn How To Be a Storm Spotter by reading the clouds at sea at www.boatsafe.com/kids/weather1.htm.

For more lessons on the marine industry visit namapa.net/education.

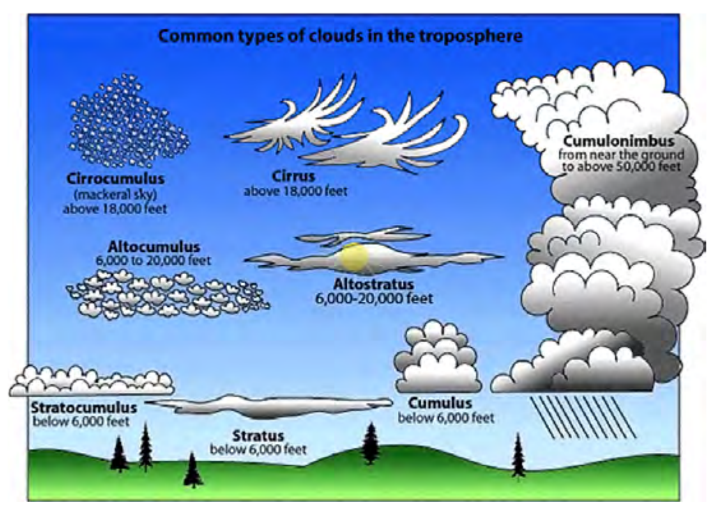


Figure 1. Common types of clouds in the troposphere

SOURCE: eo.ucar.edu

8: SOUNDS ON THE WATER

Grade Level: 6-8
Time: 25-30 min

SUMMARY:

In this activity, students will learn how vessels at sea communicate with one another using sound signals.

OBJECTIVES:

Students will:
• Learn about five different sound signals that ships use at sea.
• Communicate with each other via sound and navigate through passing, overtaking and collision avoiding situations.

STEM APPLICATIONS:

Technology - students learn how sound technology can be used to transmit signals and communicate to prevent collisions and accidents at sea.

NGSS ALIGNMENT:

• **Practice 8.** Obtaining, Evaluating, and Communicating Information

- **6-8 –** Communicate scientific and/or technical information (e.g. about a proposed object, tool, process, system) in writing and/or through oral presentations.

VOCABULARY:

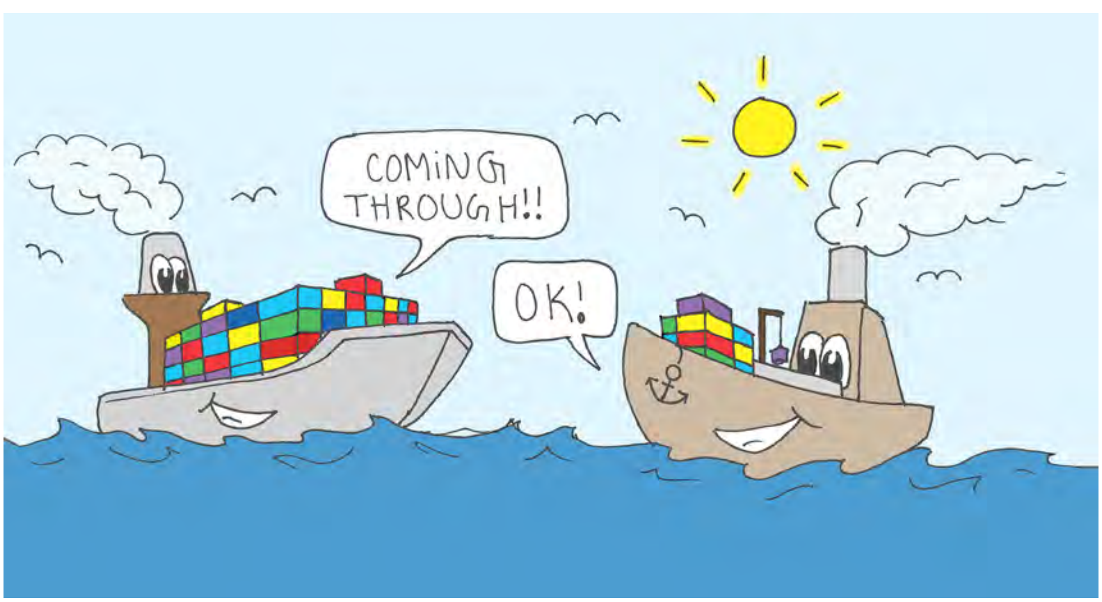
Rules of the Road – The accepted set of rules and regulations for all ships traveling on the ocean, including signs, lights, colors, sounds and situational standards that all mariners abide by.
Give Way Vessel – In a crossing, overtaking or head-on situation involving two vessels, this vessel alters its course to avoid a collision.
Stand-on Vessel – This vessel maintains its speed, direction and course while the give way vessel passes or overtakes it.
Port – The left side of a boat.
Starboard – The right side of a boat.
Overtake – When a vessel comes from behind another vessel to pass it, like a fast car passing a slower car on the highway.
Pass – When two boats travel past each other in opposite directions. Boats usually pass port-to-port, so each boat keeps the other boat on its port (Left) side.

MATERIALS:

• Index cards
• Markers
• Masking tape

BACKGROUND:

Two boats may occasionally find themselves on the same path, traveling toward each other – and one or both must move out of the way to avoid a collision. In this case, the boats must decide which direction one or both of them will turn – if they turn the same way, they might still be on a collision path! Sound signals are used to help boats avoid collisions, or in some cases, to alert other boaters of danger or call for help. Have you ever been walking down a hallway and almost bumped into someone, only to go one way and then the other as you both try to get out of each other's way? This would be a dangerous situation at sea! Ships avoid this by communicating with clear signals that let other vessels know how and where they plan to move.



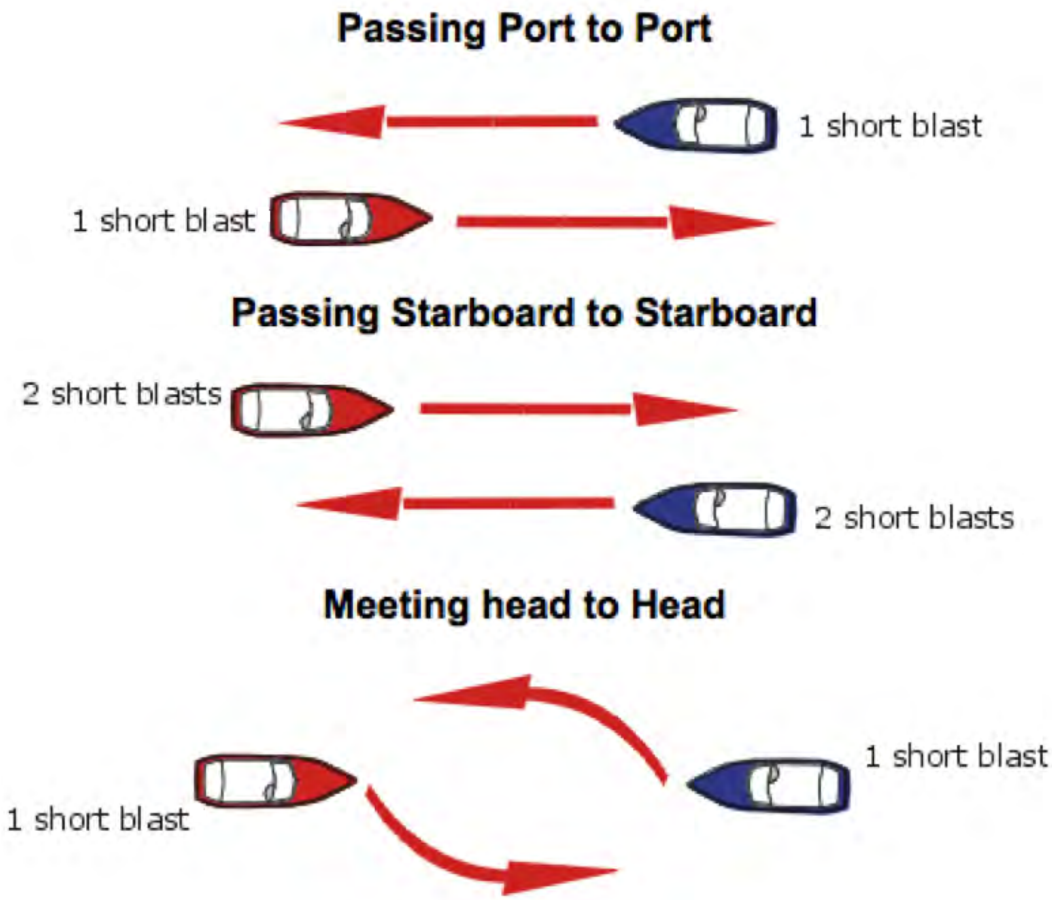


Figure 1. Passing Vessels

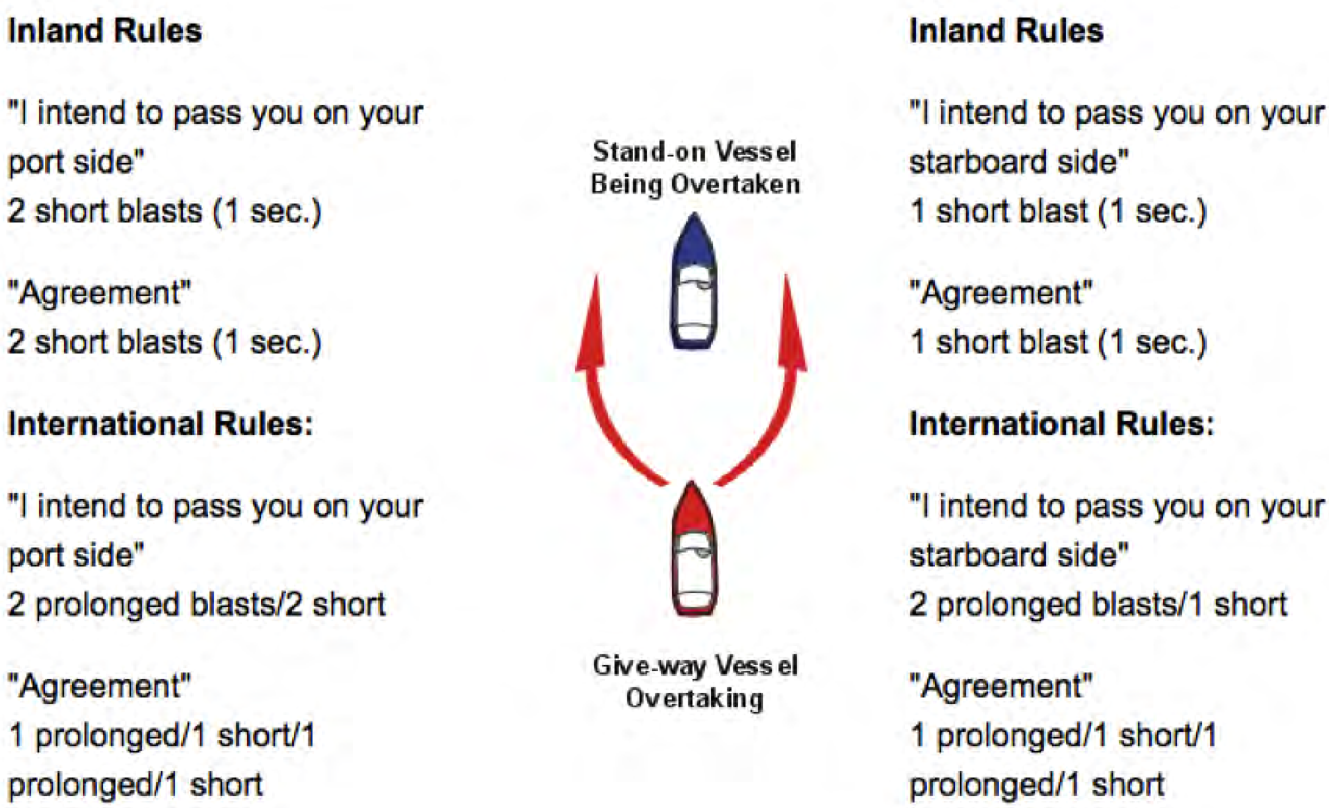


Figure 2. Passing Rules

SOURCE:boatingbasicsonline.com

ACTIVITY:

1. Engage/Elicit

Begin this activity by demonstrating each of the vocabulary terms, making sure that students understand that port and starboard are terms used to mean "left" and "right," respectively on a boat. A good way to remember the difference is that p-o-r-t and l-e-f-t both have four letters!

Explain that boats use sound signals to alert each other to the actions they intend to take when navigating on the water. These sound signals are usually made by the vessel's horn, or are sometimes blasted on a whistle, and all mariners must know what each signal means. See Figures 1 and 2 for a visual.

The common sound signals that you'll need to know for this activity are:

- **One short blast:** I'm going to turn to starboard (right)
- **Two short blasts:** I'm going to turn to port (left)
- **Three short blasts:** I'm going to back up
- **Five short blasts:** Warning – either "your boat is in danger" or "I don't understand what you communicated"

2. Explore

Divide the class into groups of four, pass out index cards and markers and ask each group to make one index card for each of the sound signals. On the front of the card, have the students write what the signal is (ex. "One short blast"), and on the back what the message is ("I'm going to turn to starboard").

Explain that when both boats understand a signal and can safely let the signaling boat perform the action, the boat must sound the same signal back in response. If it does not understand the signal or does not want to allow the boat to do an action, it must sound five short blasts to indicate this.

When this is done, ask the students to quiz each other on what each sound signal means. One student can make the sound signal (either vocally or by whistling) while the others in the group follow the direction. When the students seem comfortable with the meanings behind each of these four sound signals, gather the class together for the group activity.

3. Explain

During this part of the activity, students in the class will act out certain ship crossing, meeting, and overtaking scenarios while communicating via sound signals.

The first scenario is a crossing scenario. Have two students volunteer to be "boats," and ask them to stand so their paths are perpendicular. In a crossing scenario, the give-way vessel must change its course so that it crosses astern (in back of) the stand-on vessel, and may have to slow down and turn to do so. In order to cross in back of the stand-on vessel, the give-way vessel will have to turn to starboard, so the boat should sound one short blast. In a crossing scenario, the give-way vessel is the one that has the other vessel to starboard, or sees the other boat on its right side.

In certain cases, ships find themselves traveling along the same course in opposite directions and one or both of them must change their course in order to avoid a collision. This scenario is called meeting head-to-head, and in this case both ships must alter their course, usually by turning a bit to starboard so that the ships pass port-to-port. In this case, one ship will sound 1 blast to indicate that it will move starboard, and the other ship will sound 1 blast to say that it understands and agrees, and will also move to starboard.

Practice this situation with two students in the class who volunteer to be two vessels meeting head on. Have one student sound the 1 blast signal, and the other answer him or her with a 1 blast signal. See how both "boats" move slightly starboard to avoid a collision. Also explain that in this scenario, neither boat has the "right of way," and therefore both boats must change their course.

Practice an overtaking scenario. Just like cars on a highway, sometimes faster vessels want to pass slower moving ones by coming up from behind. In an overtaking scenario, the stand on vessel is the boat being passed, and the give way vessel is the one who is passing the other. You can run this scenario at least twice – once where the overtaking vessel passes to starboard, and once where it passes to port.

When the two students demonstrate this scenario, have one student stand about 10 feet behind the other, and ask them to start walking. When the student in the back gets close to the one in the front, tell them they can sound either one short blast (to pass on the starboard side) or two short blasts (to pass on the port side). Remind the stand-on vessel that he/she must sound the same signal in response to indicate that he/she understands and allows the give-way vessel to overtake them.

4. Evaluate/ Wrap-up

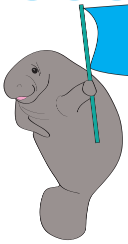
To Wrap-up this lesson, you can initiate a discussion about how and why these signals might have been developed. How does applying simple, universal code of sound signals help avoid accidents and keep mariners safe at sea? With radio technology available, it is certainly possible to communicate specifically between vessels, and this happens often. However, what are some advantages to the sound signal system?

5. Dive Deeper

To learn more about the Rules and Regulations of maritime navigation, check out the US Coast Guard's online resource, at www.navcen.uscg.gov/?pageName=navRulesContent.

A description of the sounds signals and their definitions can be found online from BoatSafe, at www.boatingbasicsonline.com/content/general/6_2_b2.php.

For more fun activities on maritime safety and to learn about the industry, please visit www.namepa.net/education.



9: INTRODUCTION TO NAVIGATION TECHNIQUES: TRIANGULATION

Grade Level: 9-12
Time: 45 – 60 min

SUMMARY:

In this lesson, students will learn about the navigational concept of triangulation, wherein the approximate position of a vessel can be determined by using basic principles of geometry. Students will first work through a practice problem to grasp the concept and see the calculations, and will then use their math skills to determine the location of a model boat in relationship to three fixed "landmarks," set up as a 3D model of the coastline.

OBJECTIVES:

Students will:

- Understand the concept of triangulation as it is used to determine approximate position in navigation.
- Use the triangulation technique to solve simple problems on location determination.

STEM APPLICATIONS:

- **Engineering** – Students create a 3D diagram to determine a location using triangulation.
- **Math** – Students use calculations including angles, circles, and trigonometry to solve problems.

NGSS ALIGNMENT:

- **Practice 1.** Asking Questions and Defining Problems
  - **9-12 –** Ask questions to clarify and refine a model, an explanation, or an engineering problem.
  - **9-12 –** Ask questions that arise from examining models or a theory, to clarify and seek additional information and relationships.
- **Practice 2.** Developing and Using Models
  - **9-12 –** Develop a complex model that allows for manipulation and testing of a proposed process or system.
- **Practice 4.** Analyzing and Interpreting Data
  - **9-12 –** Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.
  - **9-12 –** Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data.
- **Practice 5.** Using Mathematics and Computational Thinking
  - **9-12 –** Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system.
  - **9-12 –** Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units.

VOCABULARY:

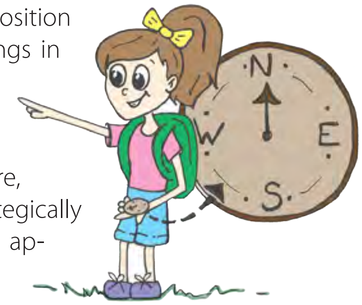
Triangulation – The tracing and measurement of a series of triangles that have points at fixed objects in order to determine relative position of a boat or other movable object on a map.
Position Fix – A position or point on a map determined from measuring external reference points.
Relative Angle – The angle that is formed between a movable object (in this activity, a boat) and two fixed objects. When the movable object moves, the relative angle between it and the two fixed objects changes.
Snellius Construction – A method of determining approximate position on a map or chart by using triangulation that was developed in the 16th century by a Dutch mathematician named Willebrord Snellius.
Compass – A navigation tool that contains a magnetized pointer which shows the direction of magnetic north, used to find exact direction.
Heading – A direction, usually the direction you are traveling in.

MATERIALS:

- Whiteboard or large piece of paper
- Picture or drawing of a compass (to illustrate degrees, used to find angles)
- Protractor
- String/yarn
- Model "boat" (can be a piece of cardboard, a block, etc.)
- 3 objects to use to determine position, labeled A, B, and C or names of objects on land (lighthouse, factory, statue, etc.)
- Masking tape (at least 2 colors: white and blue are easy to find!)

BACKGROUND:

Triangulation is a method of determining one's approximate position on a map by measuring the angles of three fixed objects relative to a movable one. This method has been useful to mariners since the 16th century, when Willebrord Snellius – a mathematician from the Netherlands – first used it to find the length of the meridian by measuring the distance between church towers in two Dutch cities. The calculations used in triangulation are the same basic principles that were used to develop modern GPS (Global Positioning System) technology. Triangulation allows a relatively precise position to be determined from three bearings in a straightforward, simple and dependable manner. A compass is used to determine relative angles from a boat to three objects on shore, and then standard geometry is strategically employed to determine the boat's approximate location.



ACTIVITY:

1. Engage/Elicit

Most students will probably know that a circle contains 360 degrees. A compass measures direction, but can also be used to measure the relative angle from your heading to an object in sight – after all, it's a circle! You can demonstrate to students that by reading the direction you are facing (which will always correspond to 360 degrees – straight ahead), and then noticing how far you'd have to rotate your body to be facing something else (say, the door, a student volunteer, etc.), you can determine the degree angle between the two objects. For example, say you read the compass and see that a student is standing at 320 degrees. You can subtract 320 from 360 (your "heading") and find that there is a difference of 40 degrees between your two positions. This corresponds to a 40-degree angle between the direction you are facing and the student's position relative to you.

Explain that this concept can be used by ships at sea to determine their approximate location. While Global Positioning System (GPS) technology has made navigation much safer and more readily accessible, sometimes it is useful for mariners to be able to determine their position using other techniques, like triangulation. This method is based on finding the relative angle of a ship to three stationary objects that are usually on land such as lighthouses, buildings, rock formations, or any other stationary object. When the relative angles are known, it is possible to calculate the location of a ship with some accuracy. When this position is compared to a nautical chart, it can help mariners navigate safely. Using three objects greatly improves the accuracy of this method, because the point where they intersect is verified in three dimensions - hence the name "triangulation."

2. Explore

Students will eventually be able to use triangulation to determine their location on their own. However, it helps to work out at least one problem as a class to demonstrate some of the calculations and present a diagram of what the students will be expected to do.

For the practice problem, use Figures 1 and 2 on the following page to draw a diagram on the board. Following the directions provided, show how the location of the hypothetical boat would be determined.

3. Extend

Keep this diagram on the board for reference during this second part of the activity, where students will be creating a 3D version of what you just demonstrated.

Divide the class into groups of 3-4 and ask the students to set up three objects in a similar formation to the practice problem. Masking tape can be used to label the objects A, B, and C, as well as to delineate a "shoreline." Ask the students to place their boat on the table, facing object "B" straight on (a 0 or 360-degree angle).

Have students measure the angles between their boat and objects A and C, respectively. They can do this by placing masking tape in a line between their boat and objects A, B, and C – just like the lines you drew in the practice problem. Have the students record these angles carefully as angle A and angle C.

Students should place lines of tape between objects A and B, and B and C, following the same protocol as the practice problem. Using blue masking tape, students should find the center of line AB and place a length of tape there at a 90-degree angle pointing offshore, toward their boat. The same should be done with line BC, so the lines are facing each other and pointing offshore.

Now, students should tape the "construction lines" at objects A and C, as in the practice problem. These lines should be drawn from lines AB and BC, respectively, at the same degree angles as angle A and angle C. So, if angle A (the angle between object A and object B from the boat) is 60 degrees, the construction line from object A should be taped at a 60 degree angle pointing inland from line AB. Follow the same rule to draw the construction line at object C.

Then, students should tape a line from object A perpendicular to the construction line they just taped. This line will lead out into the water. Tape the same line from object C – perpendicular to the construction line on that side, leading out into the water.

Students should see that these lines cross the blue lines of tape on either side. These points where the two lines of tape cross will become the center of two circles. Have the students measure a length of string from crossing point A to object A (the radius) and cut it. One student should hold the string in the center of the circle while another uses a pencil held with the other end of the string to trace a circle around the center point. The same should be done around crossing point C.

Take note of where these two circles overlap offshore. This is the position fix that has been determined by the process of triangulation! If your students are at this point, they will have figured out the precise location of the boat. If they were using a nautical chart, they would know exactly where on the chart they were.

4. Evaluate/ Wrap-up

Have the students discuss what they liked and found challenging about this activity. How was geometry used in these calculations? Ask why this method uses a triangle shape, and how finding a position from three fixed objects can possibly give an accurate reading.

5. Dive Deeper

Want to learn more about the kind of skills necessary to be a mariner? Did you know there are six maritime academies devoted to maritime education and training across the United States? Visit the Department of Transportation - Maritime Administration (MARAD) website to view a list of the academies, and click the links to learn more about the programs they offer. Check it out here: www.marad.dot.gov/education_landing_page/state_maritime_acadamies/state_maritime_academies.htm

For more fascinating information about the marine industry, please visit www.namepa.net/education.

Draw objects A, B, and C on the board like so:

Compass bearings: 320 on A, 360 or 0 on B, 050 on C.
Therefore, the angle between you in the boat and A is 40 (360-320), and the angle between the boat and C is 50 (0 +50).
Draw lines from A to B and from B to C.
Add lines (light blue) that bisect AB and BC at 90 degree angles and come out toward your boat.
Measure a 40 degree angle (identical to the angle between objects A and B from the boat) from line AB toward object A and draw a construction line inland from object A.
Measure a 50 degree angle (identical to the angle between objects B and C from the boat) from line BC toward object C and draw a construction line inland from object C.

At object A, draw a line perpendicular to the construction line, out into the water (facing right).
At object C, draw a line perpendicular to the construction line, out into the water (facing left).
The two intersections with the light blue lines that bisect AB and BC are the centers of two circles you will use to determine your approximate position.
Draw the first circle with this center and passes through points A and B.
Draw the second circle with this center and passes through points B and C.
The offshore intersection of these two circles gives us our position fix.

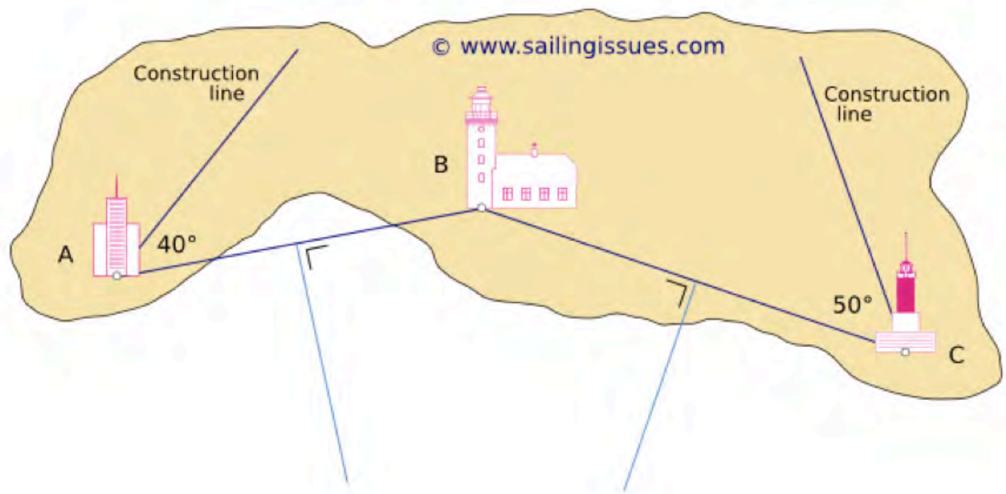


Figure 1.

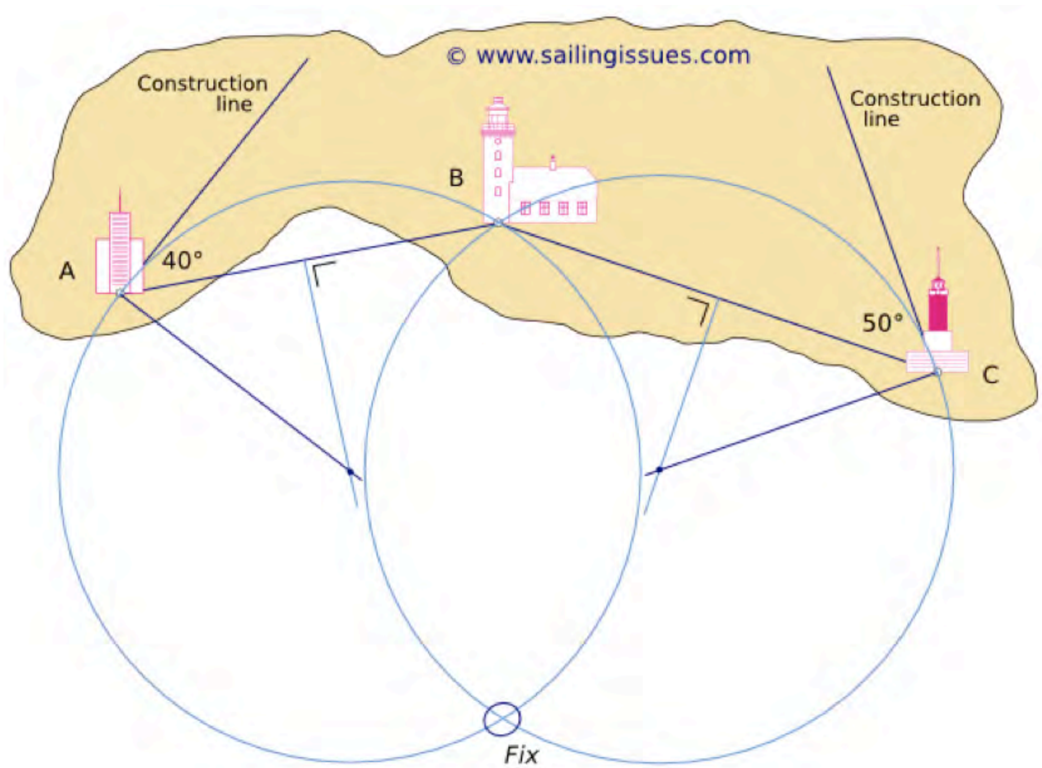
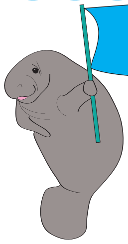


Figure 2.



Ecosystem Health

10: BUILDING A FOOD WEB

Grade Level: K-5
Time: 45 min-1 hour

SUMMARY:

In this activity, students receive organism cards and create a food web using yarn or string. Students then illustrate how species loss could impact the food web.
Note: There are enough cards for 18 students

OBJECTIVES:

Students will:
- Illustrate interactions between ocean organisms by creating a food web.
- Learn about the importance of these connections and how the removal of one or more organisms can impact the entire food web.

STEM APPLICATIONS:

- **Science (Ecology)** – Students learn about predator-prey interactions in marine ecosystems and how they impact the health of an ecosystem.

NGSS ALIGNMENT:

- **Practice 1.** Asking Questions and Defining Problems
  - **K-2** - Ask questions based on observations to find more information about the natural and/or designed world(s).
  - **3-5** - Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships.
  - **3-5** - Ask questions about what would happen if a variable is changed.
- **Practice 2.** Developing and Using Models
  - **K-2** - Develop and/or use a model to represent amounts, relationships, relative scales (bigger, smaller) and/or patterns in the natural and designed world(s).
  - **3-5** - Develop a model using an analogy, example, or abstract representation to describe a scientific principle or design solution.

VOCABULARY:

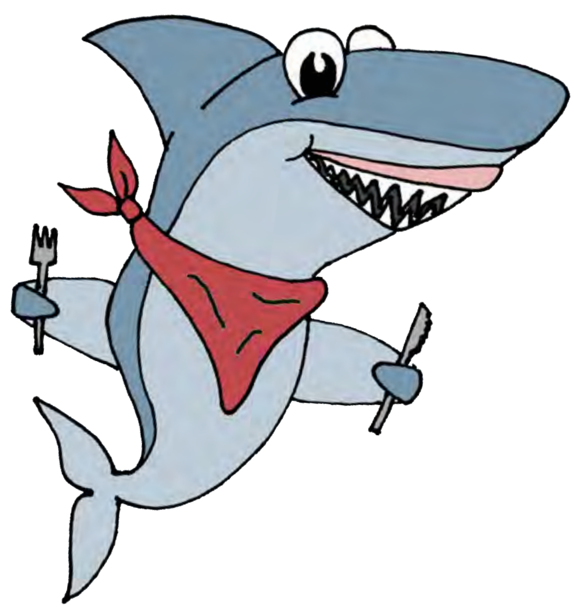
Ecosystem – A community of living things, non-living elements, and their interrelationships.
Producer – An organism that can produce its own food.
Consumer – An organism that gets its energy by consuming, or eating, other organisms.
Herbivore – An organism that consumes only plants.
Carnivore – An organism that consumes only animals.
Omnivore – An organism that consumes both plants and animals.
Decomposer – An organism that breaks down the remains of dead plants and animals.
Food Chain – A way to show how energy passes from one organism to another.
Food Web – A series of food chains that are connected to one another.
Biodiversity – The variety of life in the world or in a particular habitat or ecosystem.
Threatened Species – A species that is likely to become endangered.
Endangered Species – A species that is seriously at risk of extinction.

MATERIALS:

- NAMEPA Food Web Cards
- Tape
- Ball of string/yarn
- Scissors

BACKGROUND:

Healthy, well-balanced ecosystems are made up of many interacting food chains called food webs. In most ecosystems, organisms can obtain food and energy from more than one source, and commonly have more than one predator. A food web is one way of representing predator-prey relationships and the energy flow in a system. Looking at a food web is a great way to see the interactions between organisms and how these connections determine the health of an ecosystem. If there is an imbalance, every organism in the food web is affected. This lesson is a great way of showing how every organism plays an important role in maintaining the health of an ecosystem.



ACTIVITY:

1. Engage/Elicit

To begin this activity, ask the students if they can define "food chain." After they've answered and you have gone over the definition, ask them what a food web is. Explain that a food web is just a combination of food chains, and ask the students what they think some components of a food chain are. Answers include the sun, primary producers, consumers, decomposers, etc. Explain that producers (plants) receive their energy from the sun, consumers receive their energy from producers or other consumers, and decomposers feed on dead plants and animals. Explain to the students that they will be creating a food web with the NAMEPA food web cards and string/yarn.

2. Explore

Have the students stand in a circle and hand out an organism card to each student, telling them to take note of what type of organism they are, their predators, what they eat, and if they are threatened or endangered (only a few cards mention this). Explain what it means to be a threatened or endangered species. Have the students tape the card to the front of their shirt.

Note that one student's organism card represents humans. Explain that at any point, a student can also pass the string/yarn to the student who has this card, as humans can be a threat to any of the organisms on the food web. This may be due to fishing, habitat loss, climate change, etc. Explain that humans may impact food webs by decreasing numbers of certain species.

One student (or leader) can play the role of the sun. The sun can transfer energy only to the producers. This person will start the food web by handing the string/yarn to one of the producers. The producer will then hand the string to an organism that eats them. The food web has now begun! Each organism must toss the string/yarn to another organism to represent the transfer of energy. Be sure that the students hold on to the string every time it comes to them, and have them say the name of the organism they are throwing to before they toss it. At any point, an organism can toss the string/yarn to bacteria, and that student can toss it to any of the producers. Remind students that decomposers like bacteria release nutrients into the water that facilitate the growth of producers, making a complete cycle.

After every student has gotten the string at least once, discuss what you see. One way to initiate this discussion is to run through one or two complete chains. After the discussion, have the students who are listed as "threatened" or "endangered" (the blue whale, emperor penguin and albatross) cut their pieces of the strain/yarn in the food web and sit down. Another way to demonstrate stress on the food web is by tugging on one part and seeing how many students can feel the tug.

Note: An alternative way to use the organism cards is by having students make different food chains by stacking the cards on top of one another.

3. Explain

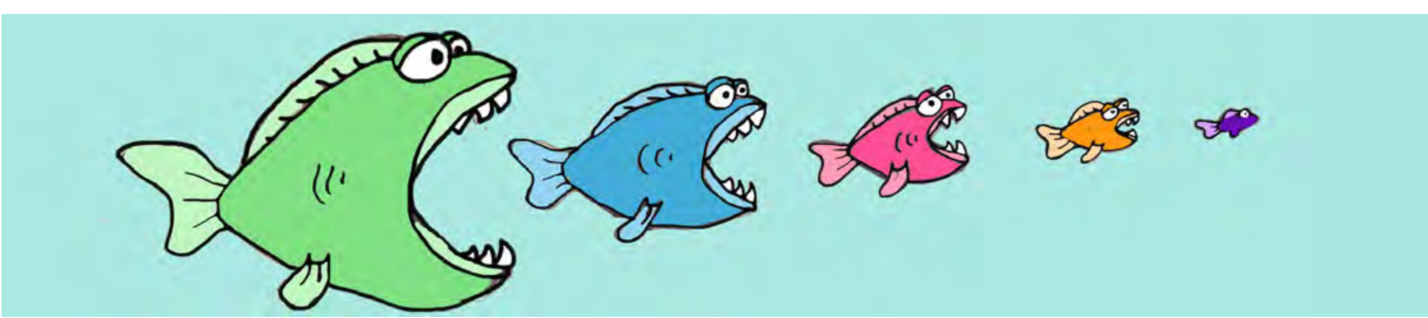
Ask the students some things they notice. What happens to the food web when the threatened/endangered species are no longer apart of it? You can mention that if certain herbivores and omnivores were removed, producers would probably start to flourish, and top predators would start to dwindle because they would not be able to find enough food. Ask students, "What organisms would have the greatest impact if removed?" A good answer to that question would be producers, because they are at the very bottom of the food chain – without them, the food chain would collapse. Explain to the students that every organism plays an important role in the food web.

4. Evaluate/Wrap-up

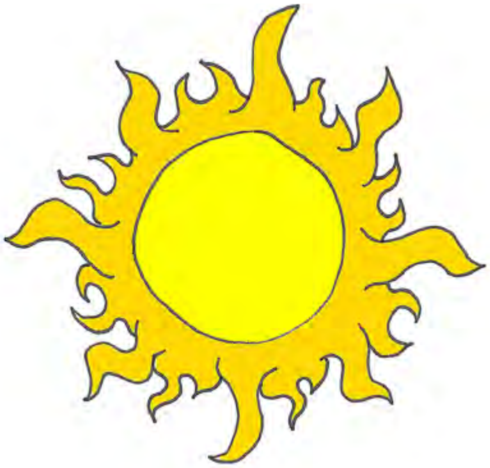
End this activity with a discussion about ecosystems and the importance of biodiversity. The more biologically diverse an ecosystem is, the more resilient it is – in other words, it can better respond to change (i.e. a storm, climate change, etc.). A simple way to explain this is that when there are more organisms in a food chain or food web, it will be less affected if one organism in that chain or web becomes threatened or endangered. When there are fewer organisms in that chain, the opposite is true. Another point to stress is that humans do not completely understand the complexity of ecosystems and how our actions are affecting the world's ecosystems.

5. Dive Deeper

This lesson is adapted from a lesson published in *Immersion: Secrets of the Gulf* by the Sea Research Foundation. To find out more about marine ecosystems, visit www.namepa.net/education.

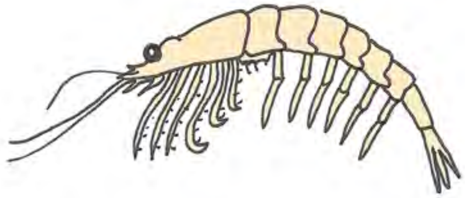


SUNLIGHT



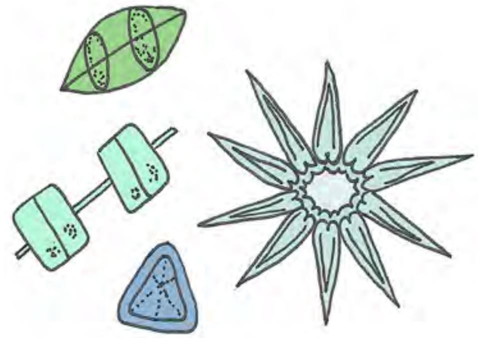
Provides energy to Producers through photosynthesis

KRILL
Consumer



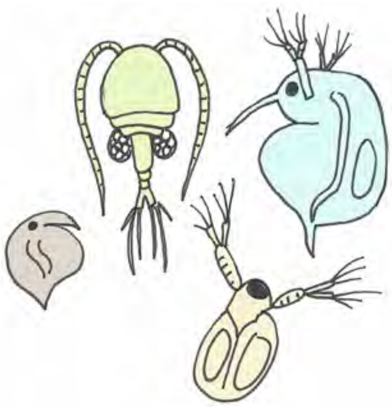
What they are: Small shrimp-like crustaceans
What they eat: Phytoplankton, Algae
What eats them: Jellyfish, Emperor Penguin, Squid, Silverfish, Toothfish, Petrel, Crabeater Seal, Blue Whale

PHYTOPLANKTON
Producer



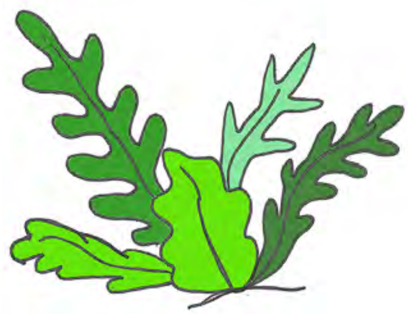
What they are: Tiny organisms that drift in the water and make their own food
What they eat: Nothing
What eats them: Zooplankton, Krill

ZOOPLANKTON
Consumer



What it is: Tiny organisms that drift in the water and feed on other plankton
What it eats: Phytoplankton
What eats them: Krill

ALGAE
Producer

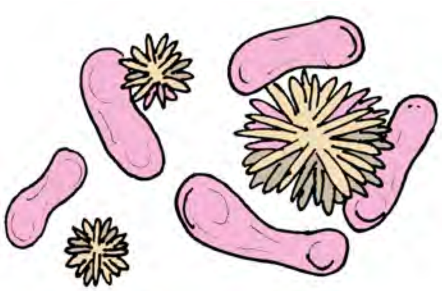


What they are: Plant-like organisms that make their own food
What they eat: Nothing
What eats them: Zooplankton, Krill

JELLYFISH
Consumer

What it is: A free-swimming marine animal shaped like an umbrella that has stinging tentacles
What it eats: Krill, Zooplankton
What eats them: Albatross, Squid

BACTERIA
Decomposer



What they are: Tiny organisms that break down dead plants, animals and other organisms and release nutrients into the water
What they eat: Anything that has died
What eats them: Nothing

LEOPARD SEAL
Consumer

What it is: A marine mammal that feeds on other animals
What it eats: Squid, Antarctic Silverfish, Emperor Penguin, Crabeater seal
What eats it: Orca

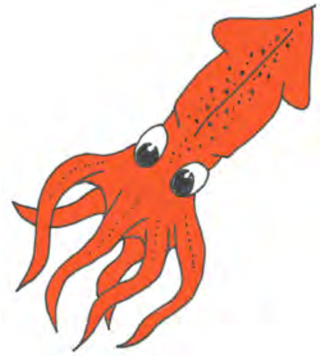
CRABEATER SEAL
Consumer

What it is: A marine mammal that feeds on other animals
What it eats: Krill, Squid, Silverfish
What eats it: Leopard seal, Orca

EMPEROR PENGUIN
Consumer

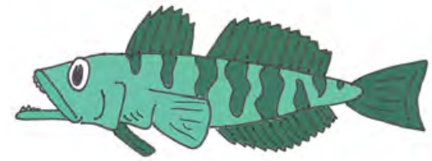
What it is: A flightless seabird
What it eats: Krill, Silverfish, Squid
What eats it: Leopard Seal, Orca
Status: Threatened

SQUID
Consumer



What it is: A fast-swimming mollusk that has tentacles
What it eats: Krill, Zooplankton
What eats it: Toothfish, Emperor Penguin, Crabeater Seal, Leopard Seal

ANTARCTIC TOOTHFISH
Consumer

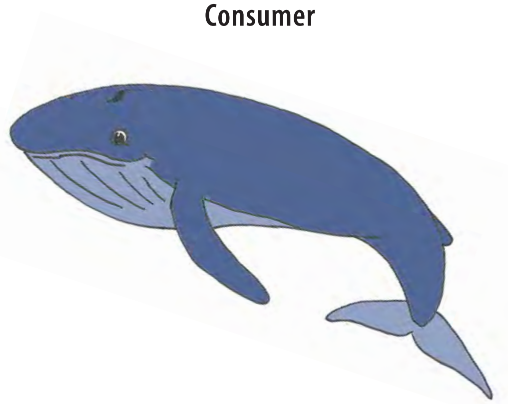


What it is: A large fish found in the Southern Ocean
What it eats: Silverfish, Squid
What eats it: Leopard Seal, Orca

ORCA
Consumer

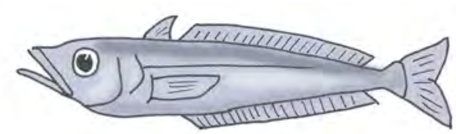
What it is: A toothed whale with black and white markings
What it eats: Silverfish, Toothfish, Squid, Leopard Seal, Emperor Penguin, Blue Whale
What eats it: Nothing

BLUE WHALE
Consumer



What it is: Large marine mammal found in all oceans
What it eats: Krill
What eats it: Orca
Status: Endangered

ANTARCTIC SILVERFISH
Consumer



What it is: A type of fish native to the Southern Ocean
What it eats: Krill, Zooplankton
What eats it: Petrel, Albatross, Toothfish, Orca

ANTARCTIC PETREL
Consumer

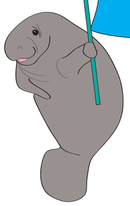
What it is: A seabird
What it eats: Krill, Silverfish, Squid
What eats it: Nothing

WANDERING ALBATROSS
Consumer

What it is: A large seabird
What it eats: Squid, Silverfish
What eats it: Nothing
Status: Threatened

HUMANS
Consumer

What we are: Mammals that have no natural predators
Threat to: All organisms through fishing, boating, climate change, etc.
Predators: None



11: SYMBIOSIS

Grade Level: 6-8
Time: 45 min- 1 hour

SUMMARY:

In this lesson, students learn about different types of symbiotic relationships between organisms and how those relationships benefit, have no effect on, or negatively affect certain organisms. Using the NAMEPA symbiosis cards, students will explore different symbiotic relationships between organisms and have to match their organism to its symbiont.

Note: there are enough cards for 24 students.

OBJECTIVES:

Students will:

- Learn about symbiosis and different relationships between organisms by participating in an activity.
- Discuss the role these relationships play in ecosystem health.

STEM APPLICATIONS:

- **Science (Ecology)** – students learn about symbiotic relationships between organisms living in the ocean.

NGSS ALIGNMENT:

- **Practice 1.** Asking Questions and Defining Problems
  - **6-8 -** Ask questions to clarify and/or refine a model, an explanation, or an engineering problem.
  - **6-8** - Ask questions that require sufficient and appropriate empirical evidence to answer.
- **Practice 3**. Planning and Carrying Out Investigations
  - **6-8** - Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation.
- **Practice 4**. Analyzing and Interpreting Data
  - **6-8** - Use graphical displays (e.g. maps, charts, graphs, and/or tables) of large data sets to identify temporal and spatial relationships.
  - **6-8** - Analyze and interpret data to provide evidence for phenomena.

VOCABULARY:

Biodiversity – The variety of life in the world or in a particular habitat or ecosystem.
Ecosystem – A community of living things, non-living elements, and their interrelationships.
Symbiosis – An interaction between organisms living in close physical association.
Mutualism – A relationship between organisms that is beneficial for both organisms.
Commensalism – A relationship between organisms where one organism benefits and the other is neither benefited nor harmed.
Parasitism – A relationship between organisms where one organism benefits and the other is harmed.

MATERIALS:

- NAMEPA Symbiosis Cards (one for every student)
- White board or chalkboard

BACKGROUND:

Ecosystems are extremely complex systems that are made up of interrelationships between species and their environments. If organisms have a symbiotic relationship, it means they live in close physical association with one another. In many cases, symbiotic relationship are imperative to an organisms survival. There are a variety of types of symbiotic relationships. The three discussed in this lesson are mutualism, commensalism and parasitism.

ACTIVITY:

1. Engage/Elicit

Begin the activity by asking the students what an ecosystem is. After taking answers, explain to them that an ecosystem is "a community of living things, non-living things and their interrelationships." Ask the students what types of relationships organisms have with each other. Answers may include predator-prey, parent and offspring, etc. If they have some difficulty with the question, prompt them by asking if there are some organisms that live near or on each other? How do they interact with one other? The term "symbiosis" may be unfamiliar to the students, so shift the discussion in that direction by providing an example, i.e. a crocodile and Plover Bird. They have a symbiotic, mutualistic relationship, meaning they both benefit from each other. The Plover eats parasites and leftover food in the crocodile's mouth. The bird gets food, while the crocodile gets its mouth cleaned. Mutualists can be described as "teammates," commensalists as "neighbors," and parasites as "thieves." You may want to write these terms on the board.

2. Explore

After going over each of the terms, shuffle the Symbiosis Cards and give one to each student (if there is an odd number of students, give yourself a card, ensuring everyone has a symbiont). Once everyone has a card, explain to the students that someone else in the class has a symbiotic relationship with them, and that they should find their "symbiont" by talking to other group members about what their organism has or needs. If students think they have found their symbiont, have them check that it is correct and then write their organisms on the board with a circle around it.

3. Explain

Once all of the pairs are written on the board, have students talk in pairs or small groups about what type of symbiotic relationship they believe those organisms have. Is it mutualism, commensalism or parasitism? To assist them, the descriptions on each card can be read aloud to the class. To take this further, students can even create their own examples of symbiotic relationships with made up organisms and share them with their peers.

4. Evaluate/Wrap-up

After determining what type of symbiotic relationship each of the students have with their symbiont, initiate a discussion about symbiosis and ecosystems. For example, you may ask:

- What could happen to an organism if its "symbiont" went extinct?
- How do you think symbiotic relationships affect the health of an ecosystem?
- What do you think are some characteristics of healthier ecosystems?

It is important to stress that if one organism is threatened or endangered, it can directly (and indirectly) affect the presence of many other organisms in that ecosystem. All species in an ecosystem are connected, and maintaining those relationships is crucial to the sustainability of that ecosystem. Generally speaking, healthy ecosystems will have a greater variety of organisms, or biodiversity.

5. Dive Deeper

NOAA's Coral Reef Conservation Program is a great resource to research and understand the immense value of coral reef ecosystems to the health of our oceans and our planet as a whole. Visit NOAA's website to learn more about they symbiotic relationship between coral and the microscopic organisms, zooanthelle, that help them survive: www.coralreef.noaa.gov/aboutcorals/coral101/symbioticalgae/.

To learn more about marine organisms and ecosystems, visit www.namepa.net/education.

ANSWER LIST:

Anemone & Clownfish (mutualism) -
Clownfish is protected by anemone and receives food scraps, anemone is defended from predators and parasites

Barnacle & Whale (commensalism) - Barnacle latches onto whale and benefits when whales swim into plankton-rich waters to feed

Whale Shark & Remora (commensalism) -
Remora travels with shark & eats scraps, shark is unaffected

Spider Crab & Algae (mutualism) -
Algae lives on crab's back, helping crab blend into environment

Cleaner Shrimp & Grouper (mutualism) -
Cleaner shrimp consumes organisms and parasites in grouper's mouth

Shrimp & Bubble Coral (commensalism) -
Shrimp uses bubble coral for camouflage and protection in coral crevices

Fish Lice & Salmon (parasitism) -
Fish serves as host for lice

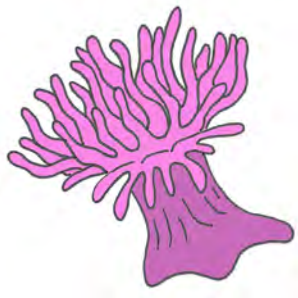
Crab & Sea Urchin (commensalism) -
Crab holds sea urchin and uses it for protection

Sea Lamprey & herring (parasitism) –
Sea lamprey attaches to host, feeding on it

Blind Shrimp & Goby (mutualism) -
Shrimp gets protection from Goby who keeps an eye on predators, Goby uses shrimp's burrow for protection from predators

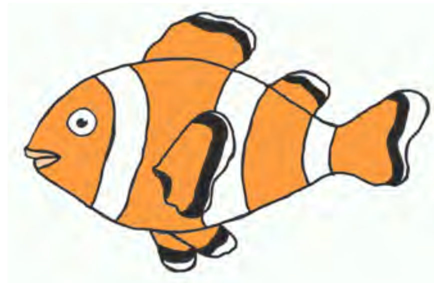
Eagle Ray & Jack (commensalism) -
Eagle ray digs up sand to get to shellfish, Jack eats small fish that are exposed as a result

Coral & Zooxanthella Algae (mutualism) –
Coral provides algae with protected environment and CO_2, algae produce oxygen and help the coral remove wastes



ANEMONE

- Has stinging tentacles that ward away predators
- Provides place to live

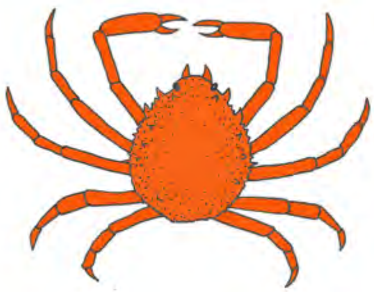


CLOWNFISH

- Needs place to live that provides protection

BARNACLE

- Filter feeder that depends on availability of plankton for food
- Latches on to moving organisms

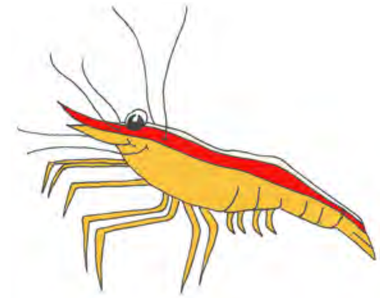


SPIDER CRAB

-Needs protection from predators
-Uses camouflage to blend into the environment

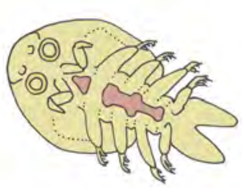
ALGAE

-Tends to grow on stationary things, but can also grow on certain animals, camouflaging them from predators



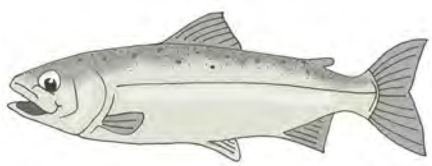
CLEANER SHRIMP

-Eats parasites and organisms from the mouths of fish



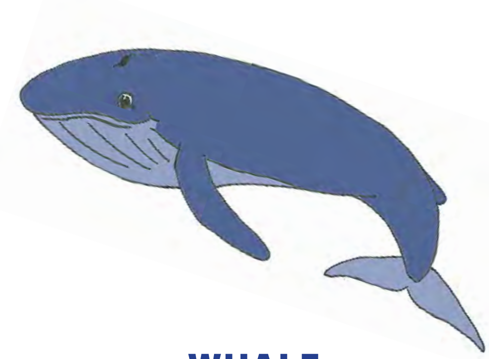
FISH LICE

-Feeds off of skin and blood of fish



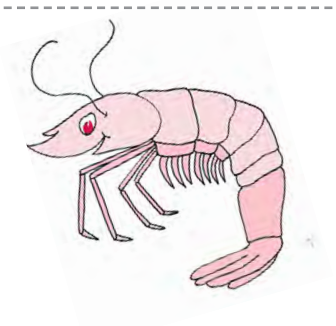
SALMON

-Saltwater fish that has skin and blood that certain organisms feed off of



WHALE

-Large mammal that often swims into plankton-rich waters to feed



BLIND SHRIMP

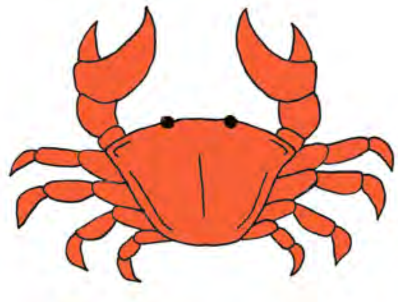
-Needs help keeping an eye out for predators
-Digs burrows for protection from predators

GOBY

-Good at keeping an eye out for predators
-Needs a place for protection

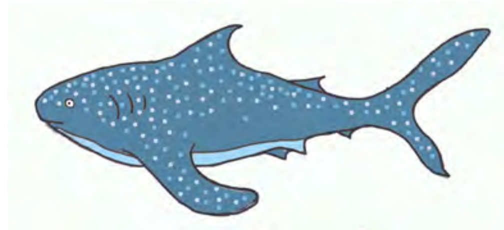
EAGLE RAY

-Digs up sand to find shellfish to eat, exposing smaller fish



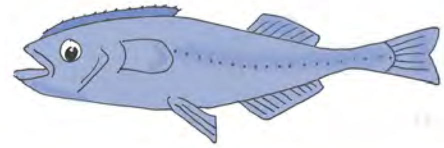
CRAB

-Has claws it can use to hold things
-Needs protection from predators



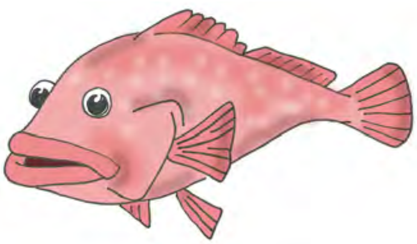
WHALE SHARK

-Leaves scraps of food behind while feeding



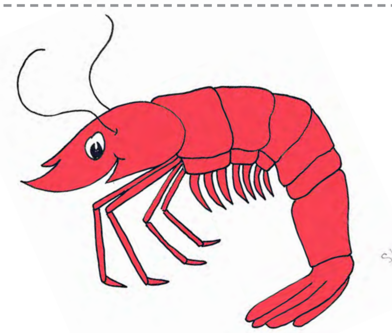
REMORA

-Consumes scraps of food left behind from other organisms



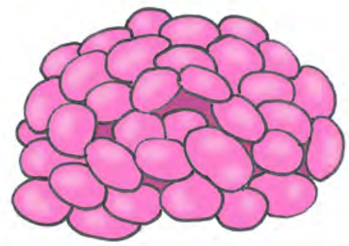
GROUPER

-Has parasites and organisms in its mouth



SHRIMP

-Needs protection from predators
-Can use camouflage by hiding

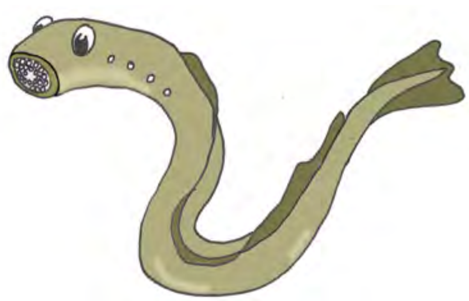


BUBBLE CORAL

-Provides place for smaller organisms to hide or blend in

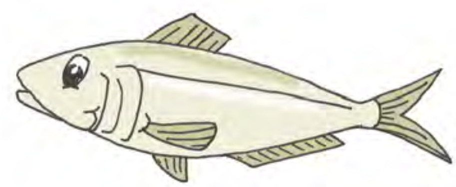
SEA URCHIN

- Has spines that shields it from predators
-Can be transported by other organisms



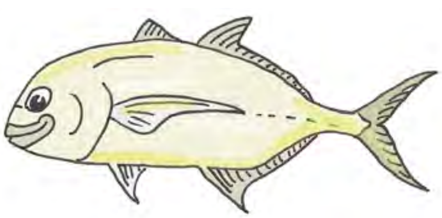
SEA LAMPREY

-Feeds on fish by using its mouth to attach to its host
-Consumes blood



HERRING

-Saltwater fish that contains blood



JACK

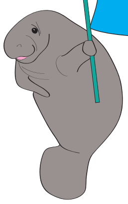
-Eats small fish that hide in the sand

CORAL

-Produces Carbon Dioxide
-Needs Oxygen
-Provides hard, protected environment for organisms

ZOOXANTHELLA ALGAE

-Produces Oxygen
-Needs Carbon Dioxide
-Needs hard place to live for protection



12: CONSERVE OR DEVELOP?

Grade Level: 9-12
Time: 1 hour

SUMMARY:

In this lesson, students are divided into groups and given a piece of property which they must decide whether to conserve or develop. Each property has a different set of characteristics that make it unique and important to the health of the ecosystem. All of the properties in this lesson are a part of the same watershed, as shown on the first map. Students need to determine what impacts their decision may have on the environment, the species in the surrounding area, and the local community. This lesson is a great introduction to ecology and land conservation and management, and illustrates how a decision to develop or conserve a piece of land can impact the local community and ecosystem.

OBJECTIVES:

Students will:
• Develop a general understanding of land conservation and ecology.
• Learn about ecosystems and how human actions affect ecosystems and their functions.
• Work together to decide what to do with their property, taking its characteristics into consideration.

STEM APPLICATIONS:

• **Science (ecology, land conservation)** – Students develop a general understanding of factors that go into land planning and how humans can impact ecosystems and landscapes.
• **Engineering** – Students must work together in groups to decide how best to utilize their parcel of land, which may include designing what their property would look like.

NGSS ALIGNMENT:

• **Practice 1.** Asking Questions and Defining Problems
  • **9-12** - Ask questions to determine relationships, including quantitative relationships, between independent and dependent variables.
  • **9-12** - Ask questions to clarify and refine a model, an explanation, or an engineering problem.
  • **9-12** - Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.
• **Practice 3**. Planning and Carrying Out Investigations
  • **9-12** - Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled.
  • **9-12** - Plan and conduct an investigation or test a design solution in a safe and ethical manner including considerations of environmental, social, and personal impacts.
• **Practice 6.** Constructing Explanations and Designing Solutions
  • **9-12** - Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.
  • **9-12** - Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.
• **Practice 7**. Engaging in Argument from Evidence
  • **9-12** - Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., tradeoffs), constraints, and ethical issues.

VOCABULARY:

• **Ecology** – The study of the relationships of organisms between one another and their environment.
• **Ecosystem** – A community of living things, non-living elements, and their interrelationships.
• **Ecosystem Services** – The benefits humans obtain from ecosystems.
• **Conservation (of land)** – The environment, lands and their natural resources are used by humans and managed in a responsible manner.
• **Preservation** – The environment, lands and their natural resources are not consumed by humans, but instead maintained in their pristine form.
• **Sustainability** – Meeting the needs of the present without compromising the needs of future generations
• **Sedimentation** – The natural process in which material (such as stones and sand) is carried to the bottom of a body of water and forms a solid layer.
• **Groundwater** – Water located beneath the earth's surface in soil pore spaces and in the fractures of rock formations.
• **Eutrophication** – A process where water bodies receive excess nutrients which stimulate excessive plant growth, which causes a lack of oxygen.
• **Biodiversity** – The variety of life in the world or in a particular habitat or ecosystem.

MATERIALS:
• Watershed Map containing all of the properties, see figure 1.
• Property characteristics of each of the properties
• White board
• Optional: PowerPoint slide showing the watershed map (available on NAMEPA website)

BACKGROUND:
As the human population continues to increase, the exploitation of natural resources increases as well. In order to continue to provide people with food, places to live, energy, water, etc., land that was once undeveloped is converted for human use. Land development can lead to habitat loss, sedimentation of rivers and streams, increased runoff, and water pollution, among other impacts, and in turn can negatively affect ecosystems and species populations. When deciding what to do with a piece of land, many factors must be taken into consideration, including ecosystem services and how local species and members of the community will be affected. There are methods used nowadays to determine what type of impact development could have, as well as how to minimize effects on the environment.

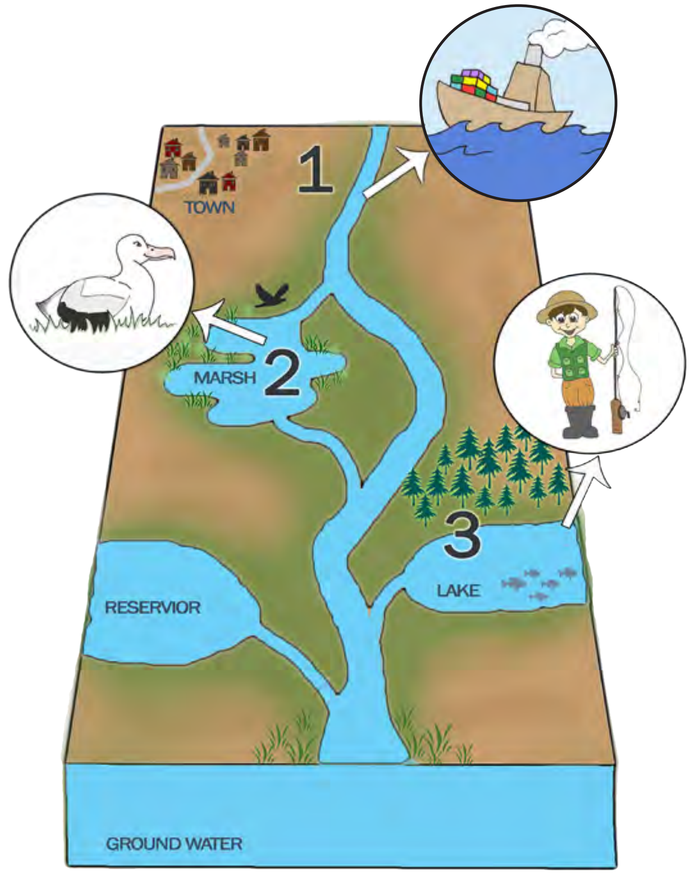


Figure 1. Watershed map sowing 3 properties

ACTIVITY:

1. Engage/Elicit
Start the lesson by asking the students what an ecosystem is. Refer to the vocabulary above for the definition. Ask the students how humans impact ecosystems.

Answers may include:
• Pollution (climate change/ fossil fuel emissions)
• Deforestation
• Overfishing
• Land development (be sure to mention if it is not said)

Ask the students if they know the difference between conservation and preservation. After taking answers, make sure the students know that preservation refers to leaving land untouched and in its natural state, whereas conservation refers to responsibly managing land for human use.

Explain that you are going to be talking about land development and how it impacts freshwater ecosystems. Before beginning the activity, ask the students if they can define "ecosystem services." After taking answers, explain that ecosystem services are the benefits humans obtain from ecosystems.

Examples of ecosystem services include:
• Climate regulation and carbon storage
• Erosion control
• Pollination

Continue with a discussion about a specific ecosystem, for an example, a wetland. Ask the students what sort of ecosystem services a wetland provides.

Answers may include:
• Flood control
• Water purification
• Shoreline protection

Shift the discussion towards freshwater ecosystems in general. What value do they provide?

Answers may include:
• Dams provide electricity
• Provide water for irrigation, industry and drinking water
• Provide us with food
• Aesthetic and recreational value

Mention that freshwater ecosystems are connected to marine ecosystems; rivers that do not flow into other rivers or lakes usually flow into the ocean. Explain that ecosystem services are extremely valuable to humans, yet they are often not taken into consideration when developing a piece of land. A primary reason for this is because it's very difficult to put a monetary value on these things.

To take the discussion further, you can talk about why it's important to protect ecosystems and biodiversity in general. Some reasons you can mention are for economic reasons, recreation, aesthetic value, for future generations, etc. The idea is to get students thinking about all of the ways that we as humans benefit from ecosystems and biodiversity.

2. Explore

Divide the students into three groups. Explain that each group will receive a different property, all of which are situated on the same watershed. Each property has a different project that is being proposed. As a group, the students must decide what to do with their property – will they develop it or conserve it? Students should make a list of pros and cons of each, and any potential impacts their decision may have. Each group should receive a copy of the watershed map showing where their property is in relation to other properties, as well as the list of property characteristics for their specific property. You could also use the PowerPoint slide available on the NAMEPA website (www.namepa.net/education./education) to project the watershed map so that all students can see it.

Points to consider during the group decision-making process:

- Future use of the property
- Will the value of the property increase or decrease with your decision?
- Will you make money from your decision?
- How could this decision potentially impact local wildlife?
- How could this decision impact the other students' properties and the local community?
- What do you think the value is of the property when it's undeveloped vs. developed?

3. Explain

Allow 20 minutes for groups to arrive at a decision and make a list of the potential effects their decision may have.

Potential impacts of development may include the following:

- Increased runoff (i.e. from removal of trees)
- Sedimentation
- Decreased habitat for local wildlife
- Aesthetic impacts
- May affect drinking water supply
- Development could help local economy

Points to consider for each property:

Property #1:

- Development could positively impact local economy
- Building the port could cause sedimentation in the river
- Other properties are downstream, so any pollution from the construction or running of port could impact those properties and the reservoir
- Because it's a partly forested property, it could help with groundwater recharge
- Forested properties also help prevent flooding
- Port could negatively impact river otter populations, affecting the local ecosystem

Property #2:

- Construction and running of dam could lead to some habitat loss for birds
- If dam was constructed, there would most likely not be a recreational fishing area
- Dam would provide renewable energy to community
- Could impact property #3 and reservoir downstream
- Dam could negatively impact other organisms living in the marsh

Property #3:

- Housing development would create new homes, in turn stimulating the local economy
- Housing development would require cutting down forest, an important habitat for birds and other organisms
- Forested habitat helps with groundwater recharge
- Development may negatively impact fishing area and reduce beaver habitat
- Construction of homes could lead to pollution in river/lake

Afterwards, each group should elect a member to present their decision, list of potential impacts, and brief explanation of their reasoning.

After having a brief discussion about potential impacts, ask the students whether or not they believe ecosystem services should be taken into consideration in the decision making process. If so, how? Engage students in a discussion about ways to determine the value of different ecosystem services.

5. Extend:

Optional: After arriving at their decisions, have the groups of students create a drawing of what could be their property if they chose to develop it. What are some things they can do to reduce the impact the development would have on the environment? Encourage them to be creative!

5. Evaluate/Wrap-up:

End the lesson by reiterating how important healthy ecosystems are to us as human beings. Tell the students that these types of decisions are made all of the time, and it is often very difficult to estimate what types of impacts land development or modification may have on ecosystems and on people. Do they think a monetary value should be placed on ecosystem services? A great way to Wrap-up this lesson is by having a discussion about ways in which a developer or homeowner can lessen their impact on the environment. Some answers may include:

- Reusing materials or using materials taken from on the site
- Using rainwater to water plants
- Recycling materials
- Planting trees to provide shade in summer and heat in winter
- Using renewable energy sources

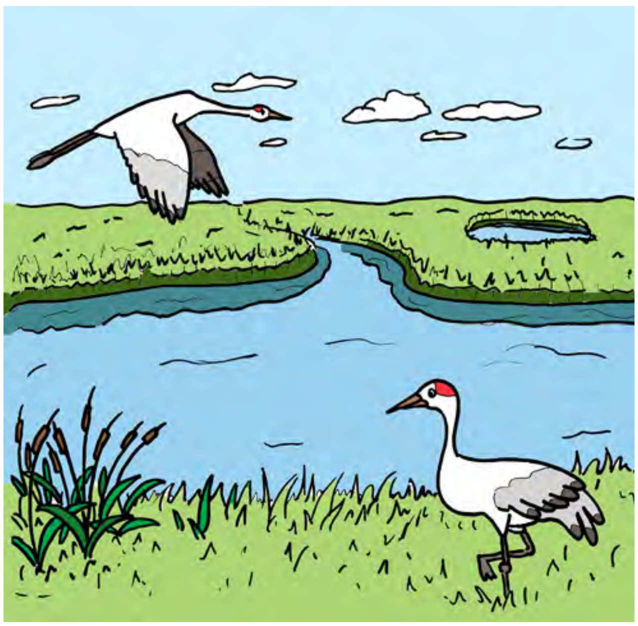
6. Dive Deeper

To learn more about land conservation, visit the Nature Conservancy's website: www.nature.org. To learn more about ecosystems and how to lessen your impact, visit www.namepa.net/education.

PROPERTY #1

Proposed Project: Port

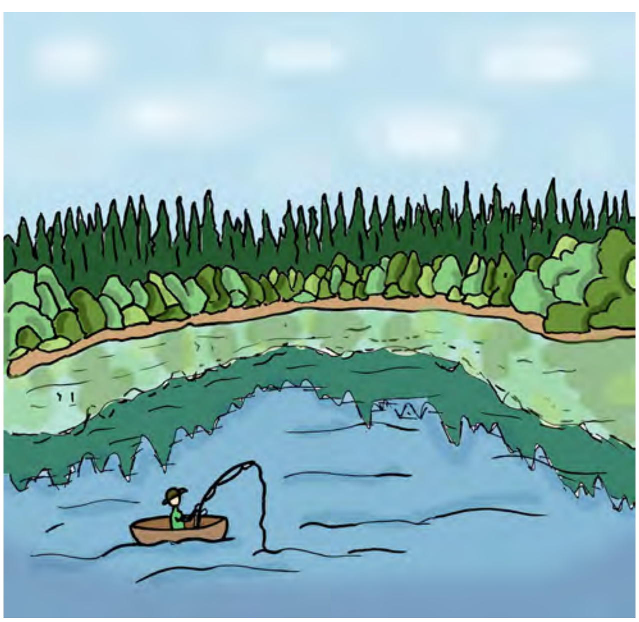
- Farthest upstream on river
- Close to local community
- Partly forested
- Important habitat for river otters



PROPERTY #2

Proposed Project: Dam

- Marsh
- Seasonal Flooding
- Important habitat for migratory birds
- Helps with groundwater recharge for reservoir
- Recreational fishing area



PROPERTY #3

Proposed Project: Housing Development

- Downstream on river
- Mostly forested
- Adjacent to lake
- Recreational fishing area
- Beaver Habitiat

GLOSSARY

Acid – A substance, like vinegar, with a low pH.

Air-Sea Gas Exchange – A physio-chemical process where differences in concentrations of certain gases in seawater and the atmosphere cause molecules to continually cross the boundary between the ocean's surface and the air.

Altostratus or Altocumulus– Clouds with the prefix "alto-" hang in the middle of the sky, not too high up or low down. Altostratus clouds look flat, and altocumulus clouds look puffy.

Amplitude – The maximum "height" of a wave, or the distance it travels away from the midline in either direction.

Aphotic or Bathypelagic zone – The bottom-most layer of the ocean, in which there is no light at all.

Automated Underwater Vehicle (AUV) – A third, more advanced type of underwater exploration vehicle that can be programmed or controlled, but does not need to be attached to a boat or external source of power in order to operate.

Bicarbonate (HCO_3^-) – A product of the chemical reaction between carbon dioxide and seawater.

Biodiversity – The variety of life in the world or in a particular habitat or ecosystem.

Brittle – Thin, breakable, fragile and/or easily cracked.

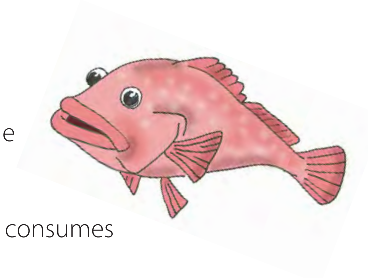
Calcification – The biological process of combining calcium with carbonate to create material that forms an exoskeleton or shell.

Calcium Carbonate ($CaCO_3$) – A material produced by mollusks and other shell-forming organisms through calcification (the two different forms of this compound are calcite and aragonite).

Carbon Dioxide (CO_2) – A gas produced by burning carbon. It is naturally present in the atmosphere, but humans have altered the carbon cycle and substantially increased the atmospheric concentration of carbon dioxide, mostly by burning fossil fuels like coal, natural gas, and oil.

Carbonate (CO_3^{-2}) – Carbonate is an ion with a negative charge that is the only bioavailable species of carbon in ocean water. Calcifying organisms combine carbonate with calcium to form shells.

Carbonic Acid (H_2CO_3) – Carbonic acid is a weak acid that forms when carbon dioxide (CO_2) reacts with water (H_2O). It is this acid, in addition to a greater concentration of free-floating hydrogen ions, that is causing the pH of the oceans to decrease.



Carnivore – An organism that consumes only animals.

Cirrus – Cirrus clouds are the highest in the sky, and are usually thin, wispy and streaky.

Coastal zone – The area at which land and sea meet and interact. This can be a beach, at a cliff's edge, protected (as in a bay) or out in the open (as an island, surrounded by water).

Commensalism – A relationship between organisms where one organism benefits and the other is neither benefited nor harmed.

Compass – A navigation tool that contains a magnetized pointer which shows the direction of magnetic north, used to find exact direction conduct research or carry out tasks underwater.

Conservation (of land) – Environment and resources are used by humans and managed in a responsible manner.

Consumer – An organism that gets its energy by consuming, or eating, other organisms.

Cumulus – Cumulus clouds are puffy and white, like cotton balls.

Decomposer – An organism that breaks down the remains of dead plants and animals.

Dissolution – When a compound such as carbon dioxide separates into individual elements by dissolving into a solvent such as ocean water, and recombines into other compound(s).

Dissolve – To break down, either quickly or over time, due to a chemical reaction.

Dysphotic or Mesopelagic zone – Also known as the "twilight zone," this layer of the ocean is in between the photic and the aphotic zone. Only certain colors on the spectrum penetrate to this depth, and light is too limited for photosynthesis to occur

Ecology – The study of the relationships of organisms with one another and their environment.

Ecosystem – A community of living things, non-living elements, and their interrelationships.

Ecosystem Services – The benefits humans obtain from ecosystems efficiently, without much resistance.

Endangered Species – A species that is seriously at risk of extinction.

Eutrophication – A process where water bodies receive excess nutrients which stimulate excessive plant growth.

Exoskeleton – A hard covering on the outside of an animal's body that helps give it structure and protect its body.

Food Chain – A way to show how energy passes from one organism to another.

Food Web – A series of food chains that are connected to one another.

Frequency – The number of wavelengths that pass a certain point in a given period of time. The unit of measure is Hertz (Hz), which reports wavelengths per second.

Give way vessel – In a crossing, overtaking or head-on situation involving two vessels, this vessel alters its course to avoid a collision.

Groundwater – Water located beneath the earth's surface in soil pore spaces and in the fractures of rock formations.

Heading – A direction, usually the direction you are traveling in.

Herbivore – An organism that consumes only plants.

Human Occupied Vehicle (HOV) – A vehicle used for underwater exploration that can hold one or more people inside of it.

Hydrodynamic – Designed to be able to move through water quickly and efficiently, without much resistance.

Intertidal zone – The area of the seashore that is above the water at low tide and below the water at high tide. It is a difficult environment for marine organisms to survive in, and these animals (like mussels, snails, and other shelled creatures) usually have adaptations to protect them from drying out in the sun or being eaten at low tide.

Invertebrate – Animals, including shellfish, that do not have a backbone.

Ion – A form of a chemical compound with either a positive or negative charge. Carbonate (CO_3^{2-}) is a negative ion, while calcium (Ca^{2+}) is positive – these equal and opposite charges allow them to bond.

Limiting Reactant – The component of a chemical reaction that is in the least supply and determines the amount of product produced.

Marine Engineer – A person who designs equipment or machinery, including exploration vehicles, for use in working with or studying the ocean.

Mutualism – A relationship between organisms that is beneficial for both organisms.

"Nimbo-" or "-nimbus" – When the prefix "nimbo-" or the suffix "-nimbus" is used to describe a cloud, it means "rain cloud." A ***cumulonimbus*** cloud is a very long, tall, "puffy" cloud that means thunderstorms are on the way.

Ocean Acidification – A phenomenon associated with climate change that is currently observable in the world's oceans. Seawater absorbs carbon dioxide from the atmosphere and in turn becomes more acidic. The impacts to marine life are unknown, but a quick change in acidity could make it hard for marine organisms – especially shell-forming ones – to survive.

Ocean Chemistry – The chemical composition of seawater and the many compounds, elements, gases, minerals and organic and particulate matter it contains.

Omnivore – An organism that consumes both plants and animals.

Optical oceanography – The study of how light behaves in the ocean.

Organism – Any living thing, which can respond to change in its environment, reproduce, grow and develop.

Overtake – When a vessel comes from behind another vessel to pass it, like a fast car passing a slower car on the highway.

Parasitism – A relationship between organisms where one organism benefits and the other is harmed.

Pass – When two boats travel past each other in opposite directions. Boats usually pass port-to-port, so each boat keeps the other boat on its port (LEFT) side.

pH – A measure of the concentration of hydrogen ions present in a substance on a scale from 0-14, where low numbers represent very strong acids, high numbers are very strong bases, and "7" (about the pH of drinking water) is neutral.

Photic or Epipelagic zone –The upper layer of water on the surface of the ocean in which light penetrates sufficiently to allow photosynthesis.

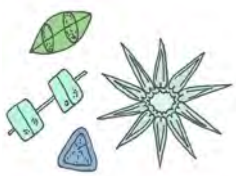
Port – The left side of a boat.

Position Fix – A position or point on a map determined from measuring external reference points.

Preservation – The environment, lands and their natural resources are not consumed by humans, but instead maintained in their pristine form.

Producer – An organism that can produce its own food.

Relative Angle – The angle that is formed between a movable object (in this activity, a boat) and two fixed objects. When the movable object moves, the relative angle between it and the two fixed objects changes.



Remotely Operated Vehicle (ROV) – A type of vehicle used by scientists to study the ocean. An ROV is attached by a cable to a boat floating on the surface, and can be controlled from there.

Rules of the Road – The accepted set of rules and regulations for all ships traveling on the ocean, including signs, lights, colors, sounds and situational standards that all mariners abide by.

Sand – The material that most often covers the ground in the coastal zone; it is produced by wave action grinding against the land along the coast. There are many different types of sand, usually identified by the size of the grain.

Sedimentation – The natural process in which material (such as stones and sand) is carried to the bottom of a body of water and forms a solid layer.

Snellius Construction – A method of determining approximate position on a map or chart by using triangulation that was developed in the 16th century by a Dutch mathematician named Willebrord Snellius.

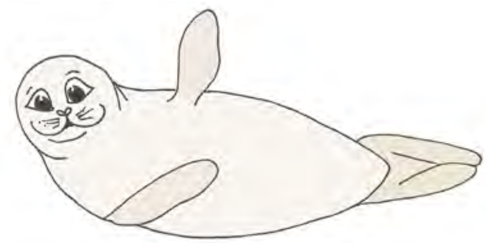
Speciation – The chemical form or compound in which an element occurs. Carbonic Acid, Carbonate, and Bicarbonate are all "species" of carbon.

Spectrum – All of the colors that make up visible light.

Speed of Light - = wavelength x frequency.

Stand-on vessel – This vessel maintains its speed, direction and course while the give way vessel passes or overtakes it.

Starboard – The right side of a boat.



Stratus – Stratus clouds are flat and horizontal.

Sublittoral Zone – The part of the ocean, close to shore, that is shallow enough for sunlight to reach the bottom.

Sustainability – Meeting the needs of the present without compromising the needs of future generations.

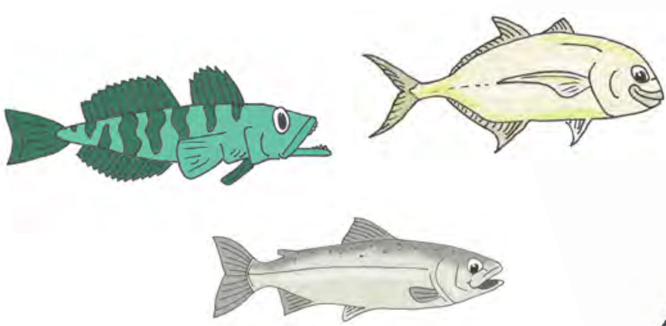
Symbiosis – An interaction between organisms living in close physical association.

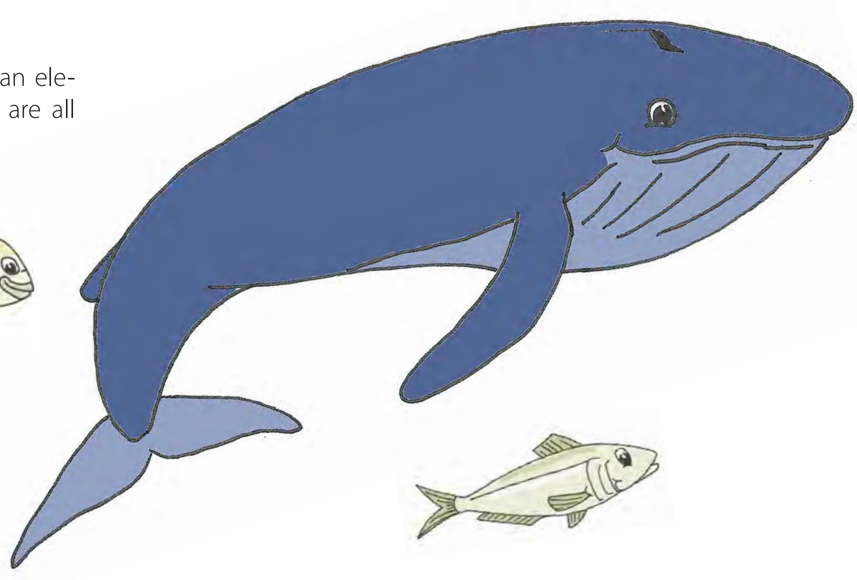
Threatened Species – A species that is likely to become endangered.

Triangulation – The tracing and measurement of a series of triangles that have points at fixed objects in order to determine relative position of a boat or other movable object on a map.

Underwater Exploration Vehicle – Any of several types of vehicles used to conduct research or carry out tasks underwater.

Wavelength – A measure of the distance between two crests of a wave. Different colors in the color spectrum have different wavelengths – violet is the shortest, and red is the longest.





Looking For More Educational Materials?

Check out our education page for additional learning guides, informational flyers and brochures!

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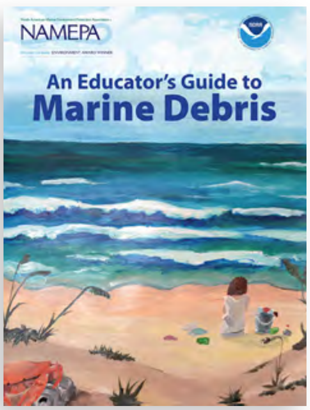
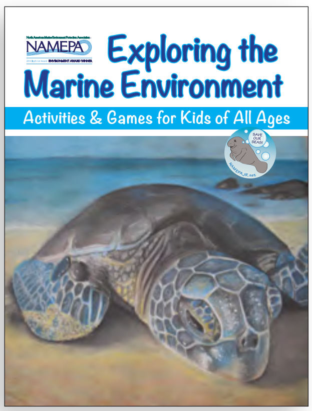
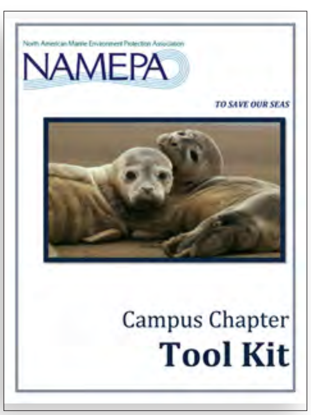


An Educator's Guide to Marine Debris – contains STEM-enhanced lessons for students K-12.

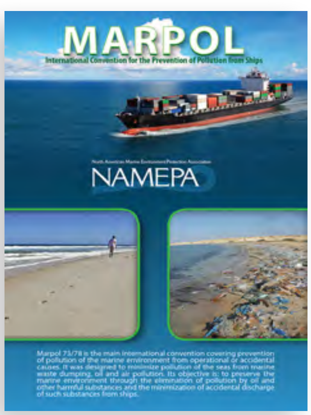


Exploring the Marine Environment Activity Book- has activities and games on the marine environment for students of all ages!

Marine Debris Poster has common marine debris items and their decomposition rates, also available in Spanish.



This toolkit contains step-by-step instructions on how to create a NAMEPA Campus Chapter at College or University!



International Convention for the Prevention of Pollution from Ships- this brochure contains MARPOL, or marine pollution, annexes on various types of marine pollution such as garbage and sewage and how they're prevented.

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