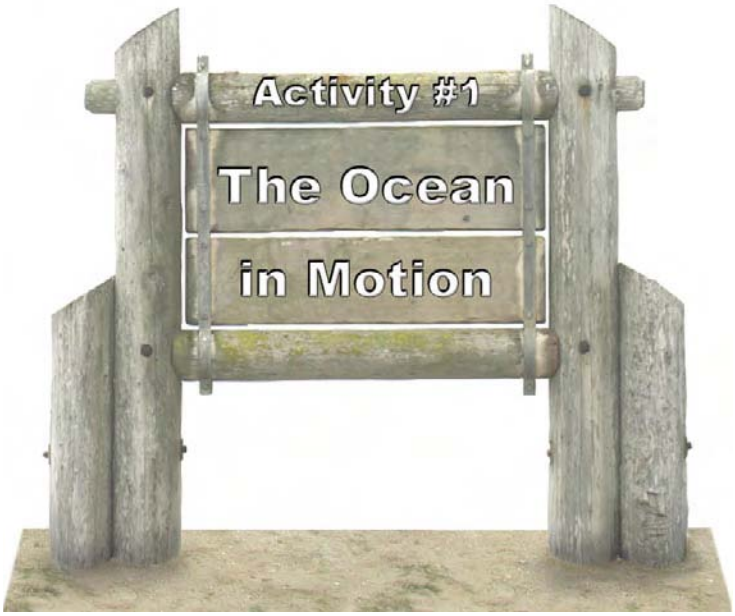
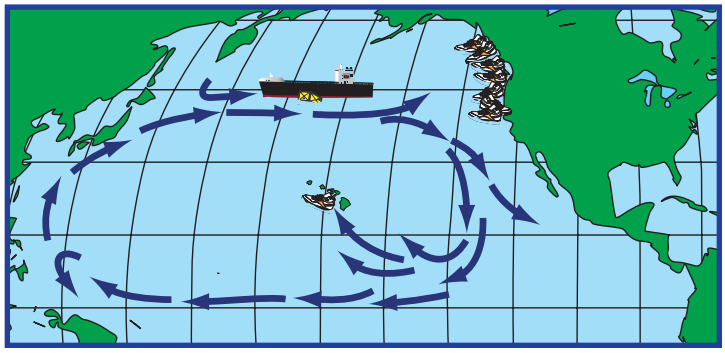
Immersion Presents *Monterey Bay*



Cool Fact 1

In 1990, a cargo ship spilled 80,000 sneakers into the northeastern Pacific Ocean. A year later, hundreds of shoes washed up on beaches in western Canada and the United States. More shoes turned up in Hawai'i in 1994. Scientists have studied the path of the shoes to learn more about ocean currents.



Cool Words

Upwelling
A process in which deep, cold water rises toward the surface

Nutrients (NOO tree unts)
Substances that all living things need to survive and grow

Phytoplankton (FI toh plank tun)
Plant-like organisms that drift in water and use sunlight to make their own food

Zooplankton (ZOH plank tun)
Animal and animal-like organisms that drift in water; most are very small

The Monterey Bay National Marine Sanctuary is home to a huge range of life—from microscopic plants and animals to enormous blue whales. Jellyfish, snails, sea turtles, sharks, giant kelp, and thousands of other species live in and around the sanctuary's waters. What makes these waters so full of life?

Wind and water currents play a big role in making the sanctuary such a lively place. Wind currents move air and water currents move water. When the movements of the air and water follow a certain pattern, they can cause **upwelling** to take place. Upwelling is a process in which deep, cold water rises toward the surface. Upwelling is very important to life along the California coast. Read on to find out how it works.

Cold water is heavier than warm water, so it usually sinks to the bottom of the ocean. The decaying remains of plants and animals also sink. Scientists call this falling matter "marine snow." Large amounts of marine snow build up on the sea floor and help make deep, cold water rich in **nutrients** (NOO tree unts). Nutrients are substances that all living things need to survive and grow. Upwelling makes deep-water nutrients available to life near the ocean surface.

Upwelling starts when winds blow warm surface water away from shore. Cold water then rises to take the warm water's place. The upwelled waters supply nutrients to the many **phytoplankton** (FI toh plank tun) that live in sunlit surface waters. Phytoplankton are plant-like organisms that drift in water and use sunlight to make their own food. Nutrients from upwelled waters are like fertilizer for phytoplankton. When there is strong upwelling along the coast of California, the surface of the water turns murky green. This is a sign that phytoplankton—and lots of them!—are blooming.

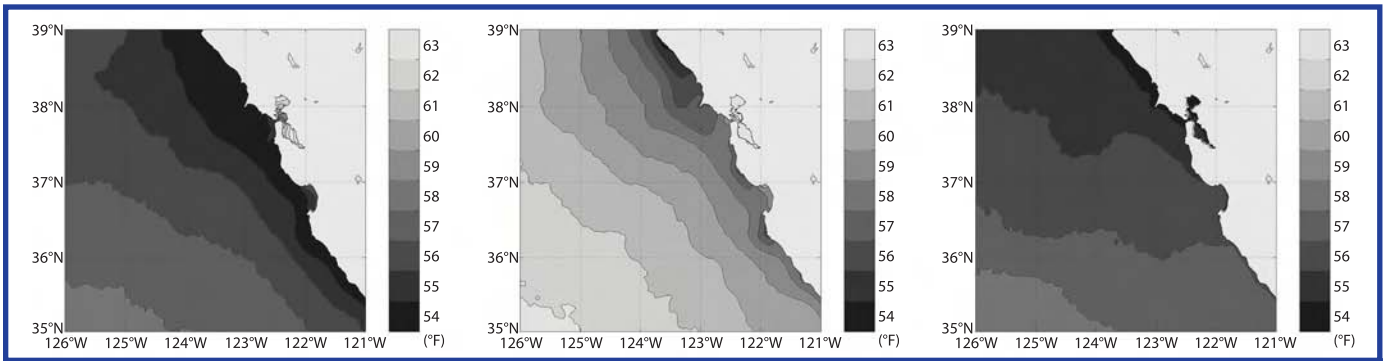
A California brown pelican dives head-first into the water to look for food.
© D. Marotta

When there are lots of phytoplankton, **zooplankton** (ZOH plank tun) have a lot to eat. Zooplankton are animal and animal-like organisms that drift in water. Most are very small. Fish, seabirds, whales, and other animals eat zooplankton. During times of upwelling, many of the creatures in and around Monterey Bay go into a flurry of feeding.

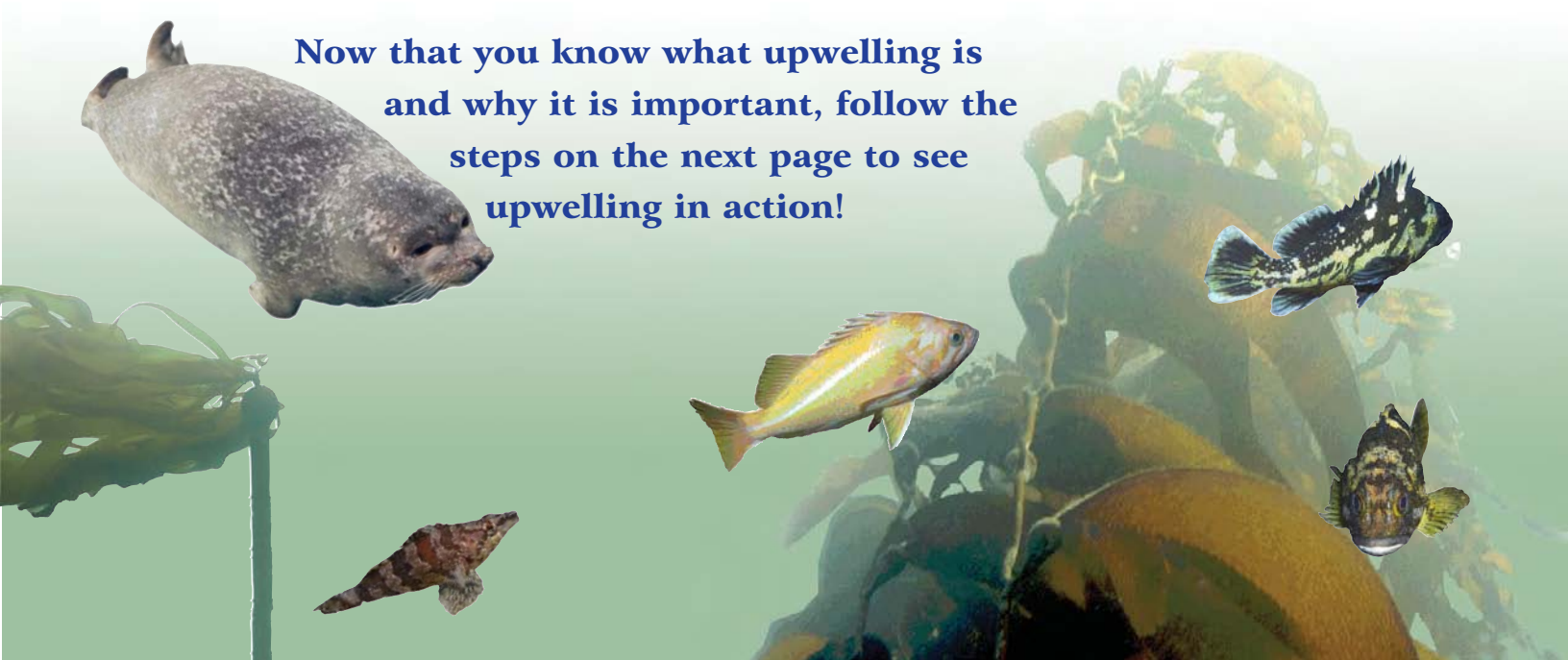
The feeding flurry slows down after winds stop blowing surface waters away from the coast. Warmer waters flow back into shore. Colder waters sink, taking nutrients with them. Fewer phytoplankton bloom and zooplankton have less to eat. Whales and other large ocean creatures begin to look elsewhere for food.

Although upwelling around Monterey Bay can happen any time that strong winds blow, it tends to follow certain patterns. The upwelling period usually takes place from March to mid-August. During this time, the California Current carries cold water south while strong winds from the northwest blow parallel to the coast. It might seem like these winds should push coastal waters southeast. But the rotation of Earth actually causes the waters to flow offshore at a right angle to the wind. This sets the stage for upwelling along the coast.

In late summer, winds from the northwest die down. So upwelling slows down and surface waters start to warm up. This lasts from about mid-August to October and is known as the oceanic period. The Davidson Current period, which usually lasts from November to February, follows the oceanic period. During this time, the Davidson Current carries warm waters north. Winds often change speed and direction during this stormy period, and there is little or no upwelling. But when winter ends, a new upwelling period begins and the cycle starts over.



These figures show the average sea surface temperature in and around the Monterey Bay National Marine Sanctuary at different times of year. From left to right, the figures show the area from March to July (the upwelling period), August to October (the oceanic period), and November to February (the Davidson Current period).



Now that you know what upwelling is and why it is important, follow the steps on the next page to see upwelling in action!

Activity

In this activity, you will model upwelling around Monterey Bay.

Materials

- clear container, at least 6 in. x 10 in. x 2 in. (18 cm x 30 cm x 5 cm)
- Monterey Bay National Marine Sanctuary Map
- tape
- 0.25 lb (110 g) modeling clay
- 1/4 c (60 mL) ice water
- cup
- 4 c (1 L) room-temperature water
- food coloring
- medicine dropper
- flexible drinking straw
- ruler

Ready to Begin?

Steps

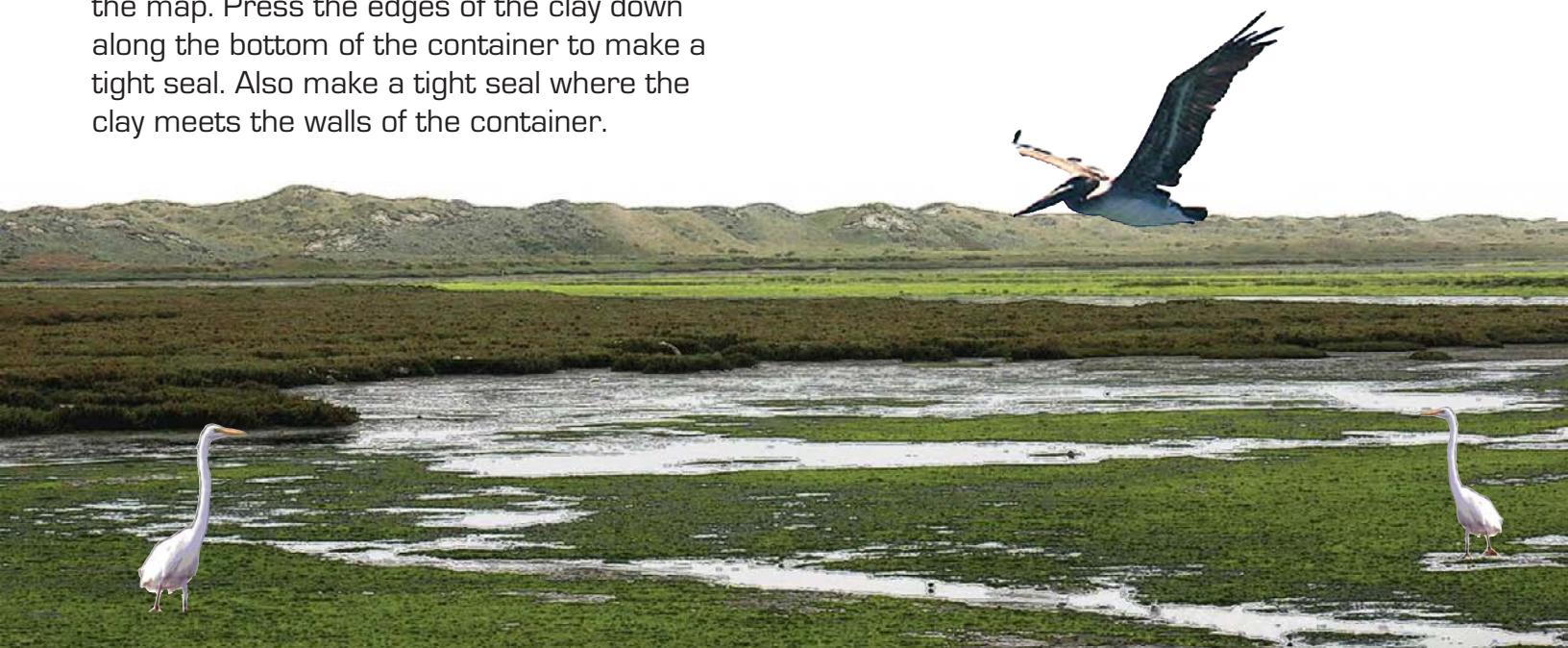
Part 1: Build the Bay

1. Place the Monterey Bay National Marine Sanctuary Map under your clear container so that you can see the map when you look into the container. Line up one corner of your container with the northeast corner of the map. Then tape the map in place.

2. Use modeling clay to build a wall 2 in. (5 cm) high to mark the coastline shown on the map. Press the edges of the clay down along the bottom of the container to make a tight seal. Also make a tight seal where the clay meets the walls of the container.

3. On one side of the clay wall is Monterey Bay—this is the ocean side of the container. On the other side of the wall is California—this is the land side of the container. Turn the container until the northeast corner of the map is the top left corner. The long ocean side of the container should be closest to you.

4. Pour room-temperature water into the ocean side of the container until the water is about 1 in. (2.5 cm) deep. If water seeps through to the land side of the container, seal the leaks with more modeling clay. Let the water settle for about five minutes before moving on to Part 2.



Part 2: Let the Wind Blow

1. Pour $^{1}/_{4}$ c (60 mL) ice water into a cup. Add five drops of food coloring to the ice water. Gently swirl the cup until the water and food coloring are well mixed.

2. Use the medicine dropper to draw out several drops of colored water from the cup.

3. Find the star on the map. Lower the tip of the dropper into the water directly over this star. When the tip of the dropper is resting on the star, slowly squeeze the bulb to release the colored water on the floor of the container.

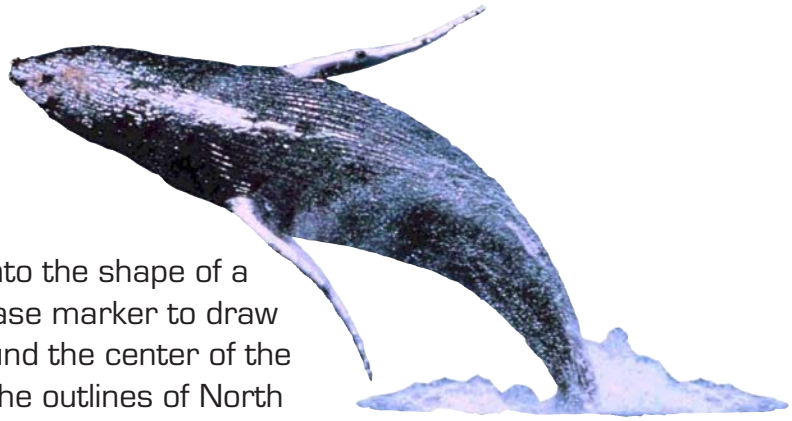
4. Observe the colored water from the side and from above.

5. Bend a flexible drinking straw at the crease to make an "L" shape. Then rest the short end of the "L" on the surface of the water and over the "place straw here" drawing on the map.

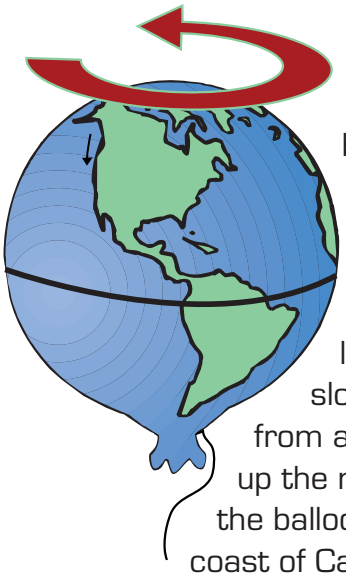
6. Take a deep breath and blow a long, steady stream of air through the straw and across the water. Do not blow into the water. Try to create small waves that move across the surface of the water.

7. Observe the colored water from the side and from above.

8. Feel free to repeat Part 2 to get another look at what happens to the colored water. Just be sure to let the water in the container settle for a few minutes before you begin again.



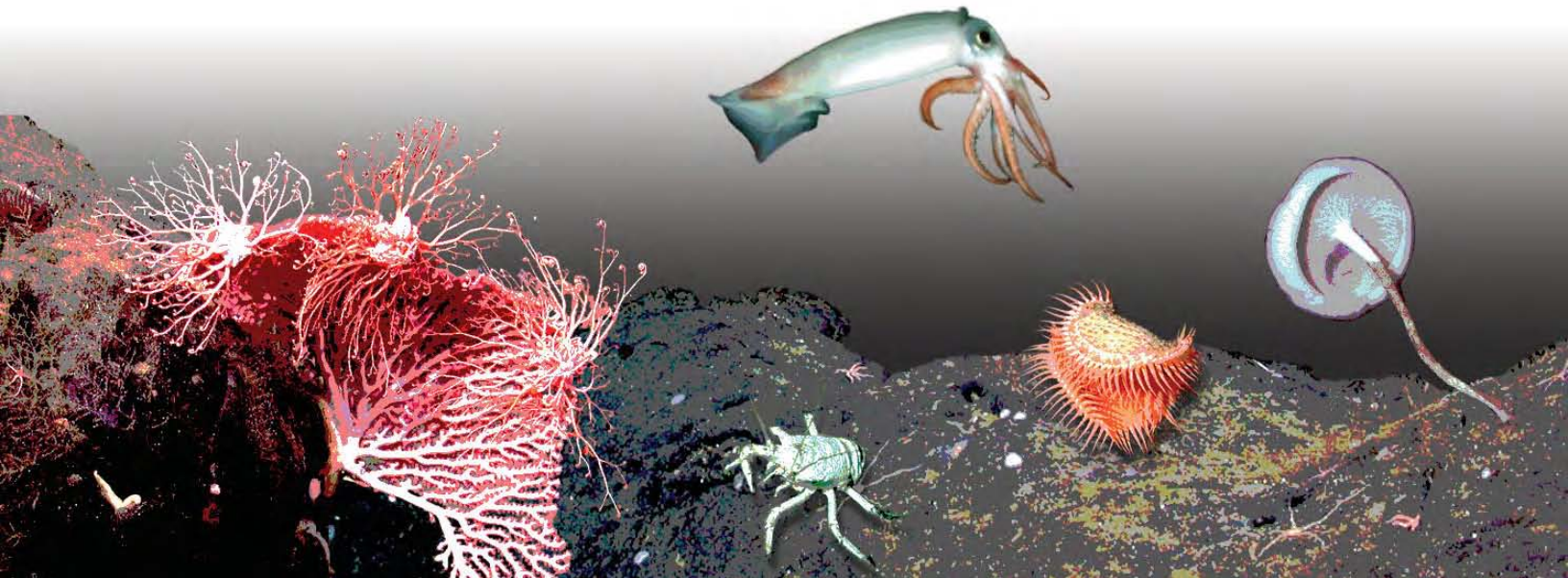
Taking It Further Activity: Watch the Water Bend



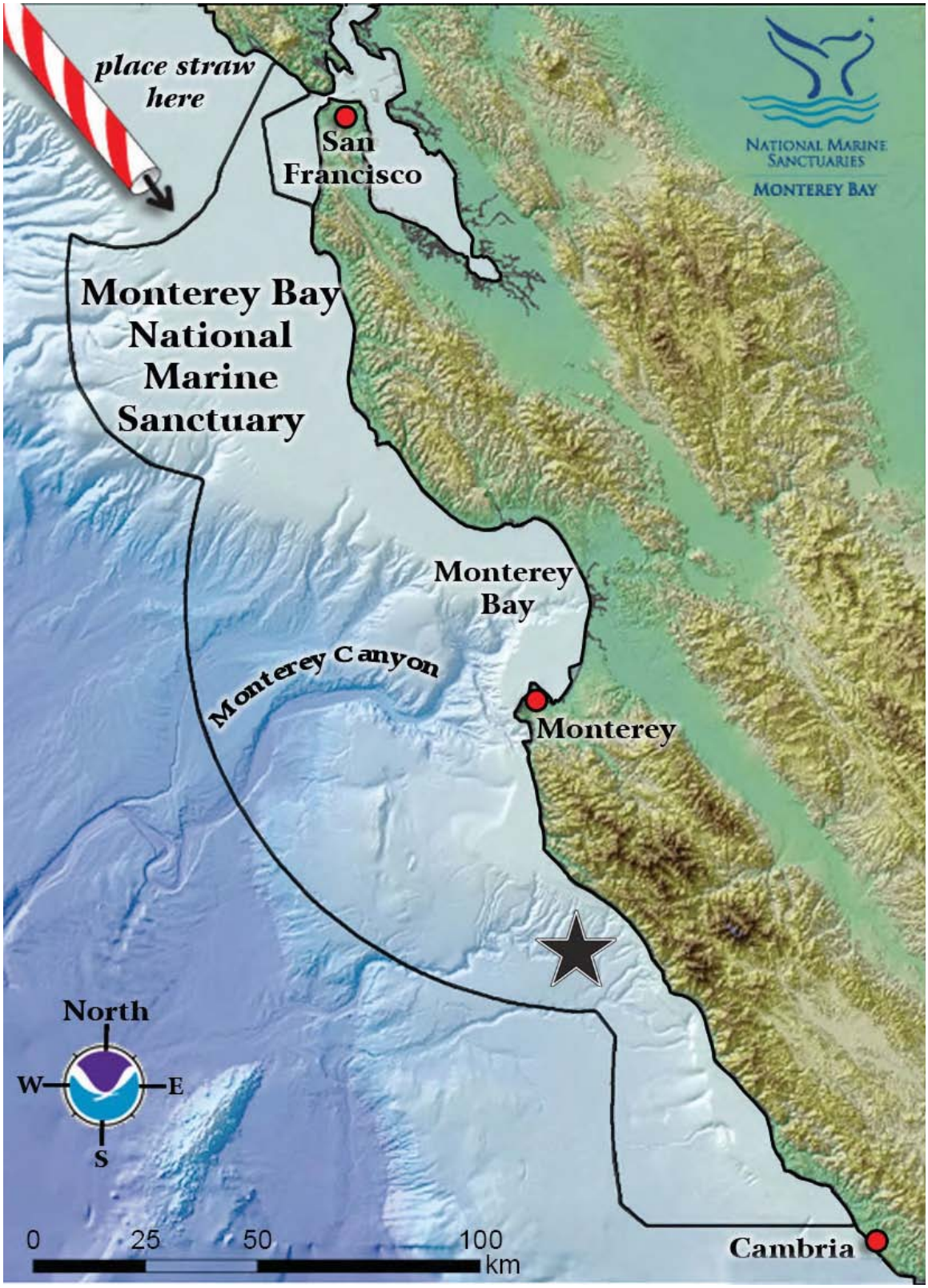
Blow up a balloon into the shape of a globe. Use a dry erase marker to draw an equator line around the center of the balloon. Then draw the outlines of North and South America on the balloon. Find the western coast of Canada and the United States. You are going to draw a line over the ocean and parallel to this coast. The line will represent winds blowing from the northwest during the upwelling period. Start the line just south of Alaska. As you begin to draw the line, have your partner slowly turn the balloon from west to east (counterclockwise when viewed from above). Continue trying to draw your line parallel to the coast, but do not lift up the marker or resist the motion of the balloon. What happens to the line on the balloon? How does this relate to what you know about upwelling along the coast of California? Switch roles with your partner and try the activity again.

Think About It

In 2005, strong winds from the northwest came about two months later than usual to the California coast. How do you think the late winds affected life around Monterey Bay that year?



Monterey Bay National Marine Sanctuary Map



Leader Notes

Summary

In this activity, participants build a model to simulate upwelling around Monterey Bay.

Difficulty: Medium

Suggested Group Size: 2

Time: 45 to 60 minutes

Goals

Participants will:

A. describe how upwelling works
B. explain how upwelling is related to the richness of marine life around Monterey Bay
C. build a model to simulate upwelling around Monterey Bay

Materials

For each group:

- clear container, at least 6 in. x 10 in. x 2 in. (18 cm x 30 cm x 5 cm)
- Monterey Bay National Marine Sanctuary Map
- tape
- 0.25 lb (110 g) modeling clay
- $^1/_4$ c (60 mL) ice water
- cup
- 4 c (1 L) room-temperature water
- food coloring
- medicine dropper
- flexible drinking straw
- ruler

For the leader:

- pitchers or empty 2-L bottles
- map that includes the entire west coast of the United States

Optional:

- towels

For the Taking It Further Activity, per group:

- balloon
- dry erase marker
- *optional:* globe or world map

Cool Words

Upwelling

A process in which deep, cold water rises toward the surface

Nutrients (NOO tree unts)

Substances that all living things need to survive and grow

Phytoplankton (FI toh plank tun)
Plant-like organisms that drift in water and use sunlight to make their own food

Zooplankton (ZOH plank tun)
Animal and animal-like organisms that drift in water; most are very small

Think About It

In 2005, strong winds from the northwest came about two months later than usual to the California coast. How do you think the late winds affected life around Monterey Bay that year?

The winds affected the timing of upwelling. In normal years, upwelling takes place throughout the spring and early summer. But in 2005, the delayed northwest winds caused upwelling to be delayed, too. Researchers noticed that there was less plankton than normal that summer. The lack of plankton led to a drop in fish catches and an increase in dead seabirds. Also, fewer whales were spotted in the sanctuary's waters that summer.

Extra Background

Participants might have heard about El Niño and La Niña events in the news. El Niño is a combination of oceanic and atmospheric events that leads to warmer than usual surface waters in the eastern tropical Pacific Ocean. It is called El Niño, which means "Christ child," because it often begins around Christmas. El Niño events happen irregularly but generally occur every three to five years. They can last from several months to more than a year. Although the warming of surface waters begins off the coast of Peru and Ecuador, global circulation patterns transmit the effects to other parts of the world.

During El Niño events, water temperatures off the coast of California typically get warmer, which affects the usual upwelling conditions. Winds are weaker, and the layer of nutrient-poor, warm surface water is thicker. These conditions prevent colder, deeper, nutrient-rich water from welling up to the surface.

During the last significant El Niño in 1998, many organisms suffered. Because surface waters didn't have as many nutrients as usual, fewer phytoplankton bloomed. This led to fewer zooplankton and less food for coastal fish populations that would have thrived during normal upwelling conditions. Top predators—especially sea lions and other species that are closely linked to coastal waters—had less to eat, and many died of starvation.

La Niña is the counterpart of El Niño. La Niña events are characterized by colder than usual surface waters in the eastern tropical Pacific. They often occur between El Niño events.

Set-Up

Make a copy of the Monterey Bay National Marine Sanctuary Map for each group. Also gather the rest of the necessary supplies.

Clear plastic rectangular storage containers work well for this activity. It is fine to use containers larger than 6 in. x 10 in. x 2 in. (18 cm x 30 cm x 5 cm)—just keep in mind that you might need to add more room-temperature water in order to create a water depth of at least 1 in. (2.5 cm).

Non-toxic modeling clay is commonly available in drugstores and arts and crafts stores. This kind of clay is often sold in 1-lb boxes with four or five sticks per box. Do not use Play-Doh® or similar clays since these kinds of clay dissolve in water.

Pour 4 c (1L) water for each group into pitchers or empty 2-L bottles well in advance of the activity. Doing this the day before the activity will allow the water plenty of time to reach room temperature.

Prepare a pitcher of ice water just before participants start the activity, but wait until they reach Part 2 before pouring the ice water into individual cups. This will help ensure that the ice water stays cold as long as possible.

You might want to have a few towels on hand in case there are any water spills during the activity.

Working With Groups

This activity works well in groups of two, but it can also be done individually or with groups larger than two. Consider having groups repeat Part 2 until each group member has had a chance to do it at least once.

Activity Notes

You might want to do Part 1 ahead of time so that you have a completed container to show participants as an example.

Before participants begin Part 1, have them look at the Monterey Bay National Marine Sanctuary Map. Ask them to find Monterey Bay, Monterey Canyon, and the cities of San Francisco, Monterey, and Cambria. Then show participants a map that includes the entire west coast of the United States. Ask them to locate the same features and cities on the larger map.

Some participants might need help building and sealing their clay walls. Explain that the wall is intended to mark the boundary between land and water and that it must be sealed tightly in order to keep the water on the ocean side from leaking over to the land side. Demonstrate how to use a finger to smear the edges of the clay to the plastic along the bottom and sides of the container. Have participants examine their wall for holes before they pour the room-temperature water into the ocean side of their container.

When it is time for Part 2, show participants how to blow across the water rather than into the water. The short end of the straw should rest on the surface of the water. Participants who create bubbles do not have the straw positioned correctly—have them lift up the end of the straw a bit to eliminate the bubbles.

Taking It Further Activity

In this activity, participants simulate how the rotation of Earth affects the direction that surface waters move relative to prevailing winds. The participant who is attempting to draw a line parallel to the coast will find the line turning offshore as the balloon is rotated. This is an illustration of the Coriolis effect, which is a deflective effect of free-moving objects due to Earth's rotation. Ocean waters are not attached to Earth, so they are subject to this effect. In the northern hemisphere, the rotation of Earth causes surface waters to be deflected to the right of prevailing winds. In the southern hemisphere, surface waters are deflected to the left. Ask participants to explain how this activity relates to what they know about upwelling along the coast of California. They should note that coastal upwelling cannot take place unless the warm surface waters along the coast are moved offshore. The Coriolis effect is what pushes the surface waters offshore at a right angle to the northwest winds, setting the stage for upwelling.

Discussion Questions

What is upwelling, and what causes it to occur around Monterey Bay? *(Upwelling is a process in which deep, cold water rises toward the surface. Upwelling often takes place around Monterey Bay when strong northwest winds in the early spring and summer push surface waters away from the coast. As the surface waters flow offshore, deep, cold waters rise up to take their place.)*

Why is upwelling important to life around Monterey Bay? *(Much of the diverse life around Monterey Bay is influenced directly or indirectly by upwelling. Upwelled waters are rich in nutrients that fuel many of the food chains in the region. Phytoplankton thrive on the nutrients and reproduce rapidly during upwelling events. Zooplankton eat the phytoplankton. And many other organisms eat the zooplankton.)*

What did the modeling clay, ice water, and room-temperature water in your model represent? What did blowing through the straw represent? *(The modeling clay represented the boundary between land and water. The ice water represented cold, nutrient-rich water, and the room-temperature water represented warmer surface water. Blowing through the straw represented wind blowing across the surface of the ocean.)*

What happened to the colored water when you first added it to your model ocean? What did this represent? *(The colored water should have spread out in a small area on the bottom of the container. It should not have mixed with the overlying water. This represents the fact that cold water is heavier than warm water and is usually layered beneath it in the ocean.)*

What happened to the colored water when you blew air across the model ocean? What did this represent? *(The colored water should have swirled upward. This represents the fact that deep, cold water can rise upward when the warmer water above it is displaced.)*

How is your upwelling model different from the real-life upwelling that takes place around Monterey Bay? *(The model represents only a small portion of the coastline. The deep, cold water in the model was not as deep as in real life. Also, the deep water was positioned in only one place along the coast rather than in multiple places. The air blown across the model ocean was not steady and did not last for months. Unlike Earth, the model did not rotate, so the surface waters were not pushed away at a right angle to the wind.)*

Additional Information

Books

A Natural History of the Monterey Bay National Marine Sanctuary, edited by Michael A. Rigsby.

Tracking Trash: Flotsam, Jetsam, and the Science of Ocean Motion, by Loree Griffin Burns.

Videos

COSEE West's *Ocean Tube: Movies and Animations: Phytoplankton* Video [online]

Web Sites

Immersion Presents Web site

Monterey Bay Aquarium Research Institute's *Education and Research: Testing Hypotheses: Coastal Processes: Upwelling Case Study* Web site

Monterey Bay National Marine Sanctuary Web site

NOAA National Environmental Satellite, Data, and Information Service's *Investigating the Ocean: Ocean Upwelling* Web site

NOAA National Marine Sanctuaries' *Ecosystems: Connected by the Currents* Web page

NOAA National Ocean Service's *Currents Lesson Plans* Web page

NOAA Ocean Explorer's *Sanctuary Quest: Upwelling* Web page

NOAA Office of Oceanic and Atmospheric Research's *El Niño* Web site

OceansLive Teachers' *Oceans for Life: Biodiversity* Web page

The Weather Doctor's *Weather Phenomenon and Elements: Of Shoes and Ships and Rubber Ducks and a Message in a Bottle* Web page

Windows to the Universe's *Currents of the Ocean* Web page

Note: Links to all Web resources can be found at www.immersionpresents.org/monterey/links.html.