



Mangrove Mania

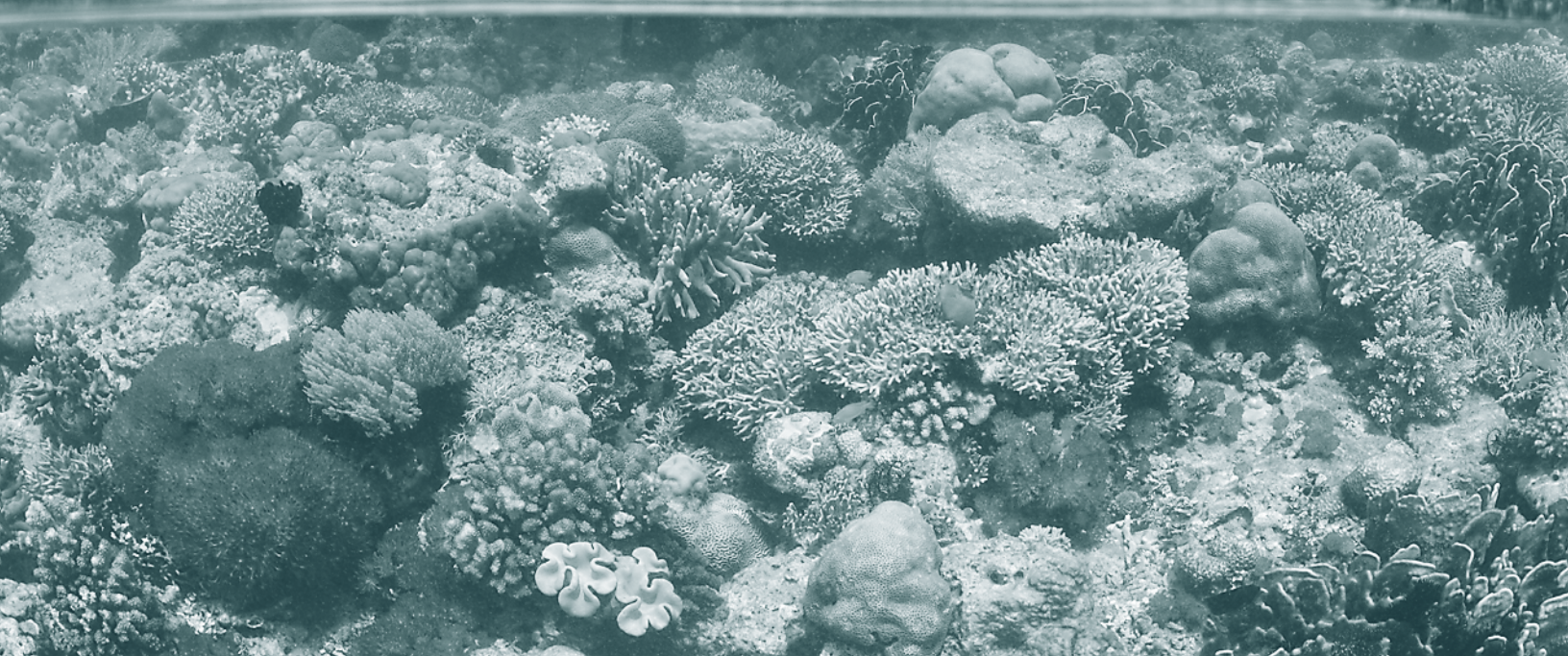


Photo courtesy of Brandon Cole Marine Photography.

***How Elevation Change
and Sea-Level Rise Affect
Mangrove Forests***

Meet the Scientists



◀ **Dr. Ken W. Krauss**, Ecologist: My favorite science experience is working directly with **land managers** to communicate the results of our scientific studies. Sharing this information helps the managers make important

land management decisions. I also enjoy the publication process, and I appreciate learning from other scientists with different viewpoints. **Peer review** and criticism promote excellence in science. In the picture, I am scouting for new tidal freshwater forested wetland study sites in the Savannah National Wildlife Refuge located in South Carolina.

▶ **Dr. Jim Allen**, Forest Ecologist: My favorite science experiences have been those that involve the opportunity to discover new things about forests. I enjoy working with the people who depend on the forests I've studied. I've also enjoyed all the travel opportunities that a career in science has provided. I have done fieldwork in beautiful places like Micronesia and the cypress swamps of the Southern United States. I have presented my research results at conferences in places like Alaska, Italy, and New Zealand.



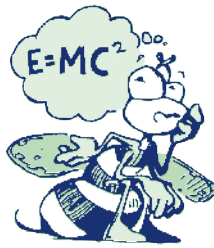
▶ **Dr. Katherine Ewel**, Wetland Ecologist: My favorite science experience was working with people in another culture to help them see their natural environment from a different viewpoint. Making the right management decisions often depends on seeing a problem from many angles.

▼ **Ms. Nicole Cormier**, Ecologist: My favorite science experience has been traveling and working on tropical islands like those in the Federated States of Micronesia (FSM). I have been fortunate to work in old growth mangrove forests. I have also worked in one of the largest remaining freshwater *Terminalia* (a type of large tree) forests in the world on Kosrae, FSM. I learned a lot about how sea-level rise and climate change affect the mangrove ecosystem and its links to nearby fishing areas and to **coral reef** health. I have also learned how different cultures are linked to the forests and are dependent upon these mangroves for coastal protection, firewood, and fish.



Glossary words are in **bold** and are defined on page 49. Hawaiian words are in *italics* and their pronunciation is given on page 106.

Thinking About Science



Many different types of measurement are used in science. Measurement helps scientists compare things and make predictions. In this study the scientists measure several different **variables** over several years. Measuring something over time helps scientists figure out what might happen now and in the future.

To take **accurate** measurements, scientists use a lot of different types of **instruments**. You may use different instruments like beakers and scales in your science lab at school. Scientists

use these types of instruments as well as computers and calculators. Using the right instruments and making accurate measurements is important. In this study, you will learn about an instrument that scientists used to measure changes in the amount of soil on the surface of the land on two islands. This instrument helped scientists compare the amount of soil and **sediment** on the islands and enabled them to make predictions about future changes on these islands.

Be sure to read
“Unity in
Diversity”
on page 52.

Thinking About the Environment

Islands are constantly changing. The islands in this study are located in the **tropics (figure 1)**. The islands started as volcanic islands. Over time, rocks and other **debris** break down and sediment is formed. Environmental forces like wind and water move the sediment around.

The amount of sediment that is deposited changes the **elevation** of the land. On these islands, the change in elevation might be small. Even so, small changes could have large effects. Changes in elevation may lead to changes on the island. In the tropics, the changes in elevation and losses of sediment eventually cause the volcanic island to support a **barrier island** that then becomes an **atoll (figure 2)**. In this study, scientists were interested in how the elevation changes due to changes in sediment and a rise in sea level affect a certain type of forest called a mangrove forest.

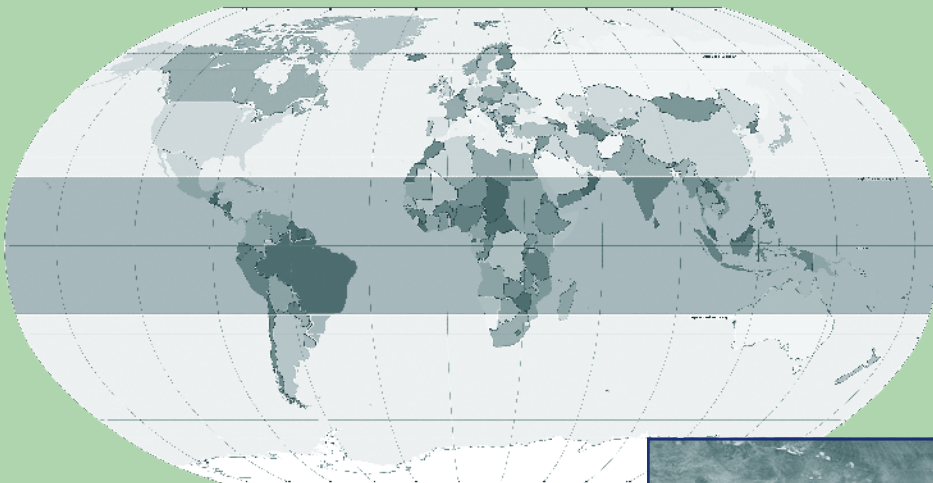
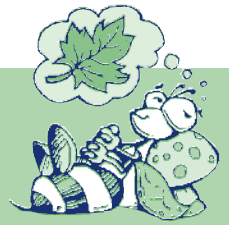


Figure 1. The tropics are near the equator. Image courtesy of <http://upload.wikimedia.org>.

Figure 2 (right). An atoll has a reef around a lagoon. This is the Pearl and Hermes Atoll, part of the Hawaiian Islands National Wildlife Refuge. Photo courtesy of the U.S. Fish and Wildlife Service.



Introduction

The scientists studied two islands, Kosrae and Pohnpei, in the Federated States of Micronesia (**figure 3**). Both of these islands have coastal mangrove forests (**figures 4a and 4b**). Mangrove forests are trees and shrubs found in the tropics that have large root structures and create barriers that help protect coastlines. These mangrove forests provide many benefits. The mangrove forests provide protection for the villages, agricultural areas, and other things on the island. This protective benefit is one way mangrove forests also help support the island's economy. These forests provide homes for fish and other wildlife. Because the mangrove forests are so important, the scientists in the study wanted to know how different elevation changes on the islands and sea-level rise affect mangrove forests.



Figure 4a (top) and figure 4b: Mangrove forests provide many benefits to people, animals, and land. Give one example of a benefit by looking at these pictures. Photos by Brandon Cole Marine Photography.

Figure 3. Kosrae and Pohnpei islands are located in the Central Pacific Ocean. Photo courtesy of USDA Forest Service/The Nature Conservancy.

What is sea-level rise?

Sea-level rise is the amount that sea level changes over time. Over the past 20 years, sea level has risen 3.302 millimeters a year. The rise in water levels has been linked to several things. One possible cause of sea-level rise is melting ice caps, glaciers, and ice sheets. Scientists are now studying other possible contributing factors. Scientists are interested in sea-level rise because as the sea level rises, some land that was once dry will be covered in water. Sea-level rise can also cause more erosion, flooding, loss of habitat, and **contamination of aquifers**. Sea-level rise can impact us in more ways. To learn more, visit <http://ocean.nationalgeographic.com/ocean/critical:issues:sea-level:rise/>.

Number Crunches

- How many inches did sea-level rise in the past 20 years? (Hint: Take amount of millimeters and multiply it by .039 to find out!)

Reflection Section

- Mangrove forests provide homes for fish and other wildlife. How could this help support the island's economy?
- What did the scientists want to learn in this study?



Methods

The scientists chose to study three different types of areas in which mangrove forests grow. The three areas were fringe, riverine, and interior. Fringe areas are on the exterior of the island and are subject to more wave action. Riverine areas are closer to rivers. The interior areas receive more protection from the waves, but are more affected by humans. On each island, the scientists chose two **river basins** to study. The scientists also included a **backswamp** area on Kosrae Island called Pukusruk (**figure 5**). Pukusruk was not directly affected by the river and is also protected from direct wave action (**figure 6**).

Kosrae Island	Pohnpei Island
1) Yela River	1) Enipoas River
2) Utwe River	2) Sapwalap River
3) Pukusruk (backswamp)	

Figure 5. Study locations on each island

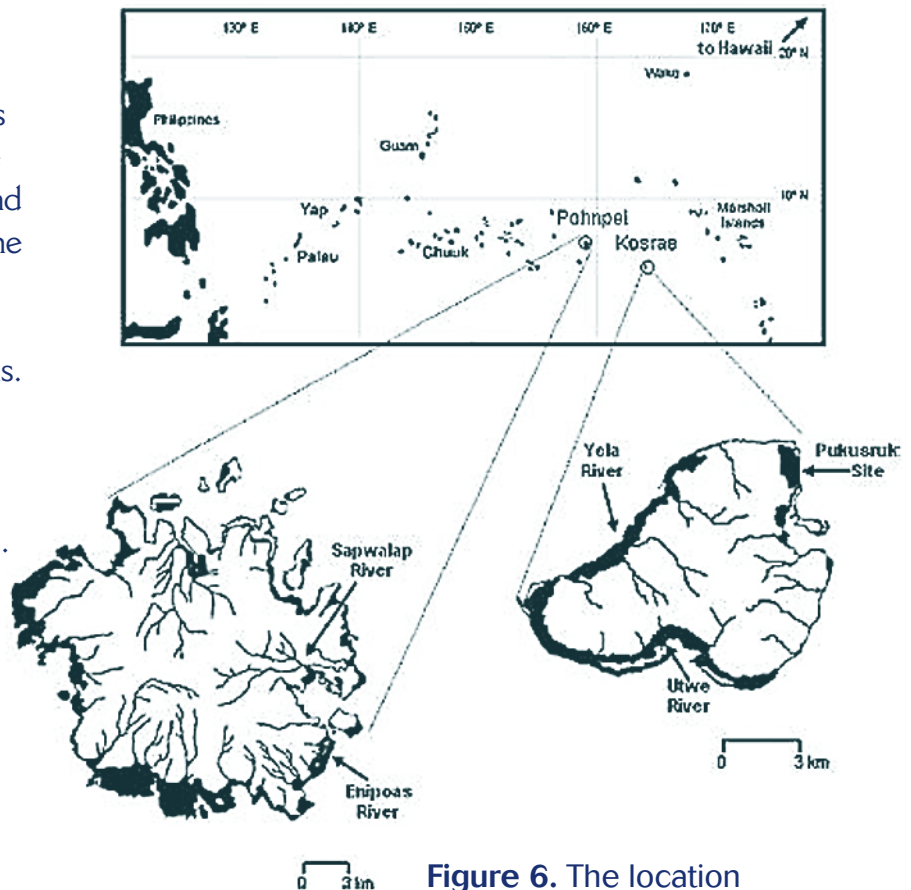


Figure 6. The location of each study site. The shaded areas are areas with mangrove forests.

At each of these sites, the scientists installed a surface-elevation table (SET) and aluminum pipes (**figure 7a and 7b**). The SET helps scientists figure out the **vertical** changes in soil surface. The SET enables the scientists to take repeated elevation measurements over time. The scientists arranged the SETs in four different directions in each measurement area. This arrangement enabled the scientists to take 36 measurements during each measurement period. A total of 39 SET pipes on the 2 islands measured conditions for 5 to 7 years. The scientists also measured the amount of **sedimentation**. The scientists placed 99 markers throughout the study areas (**figure 8**) and used a ruler to measure the sediment layer over time.



Figure 7a. The surface-elevation tables (SETs) helped to measure the vertical changes in the soil.



Figure 7b. Forest Service Ecologist Ken W. Krauss, now with the U.S. Geological Survey (USGS), takes surface elevation measurements in a mangrove forest on the island of Kosrae, Federated States of Micronesia. Photo courtesy of Dr. James A. Allen, Forest Service.



Figure 8. The scientists placed the markers throughout the study sites to measure sedimentation. Photo by Dr. Ken Krauss, USGS.

The scientists also gathered data on sea-level rise. The scientists had data on sea-level rise for Pohnpei but they did not have it for Kosrae Island. To be consistent and use the best possible data, the scientists used general sea-level trend data for the entire area in their calculations.

Reflection Section

- 🌿 Why do you think the scientists chose two different islands to study?
- 🌿 Why do you think scientists measured the islands for 5 to 7 years instead of just 1 or 2 years?



Findings

The riverine and interior zones along the Utwe River and the interior zone along the Yela River built elevation over the 6-1/2-year period (**figure 9**). Soil elevation at Pukusruk increased slightly until early 2002 when there was a **harvest** of nearby **overstory** trees. Then soil elevation decreased by 21 millimeters.

Location	Elevation Change
Yela Interior	0.91 millimeters/year
Utwe Riverine	3.29 millimeters/year
Utwe Interior	4.08 millimeters/year

Figure 9. Yearly elevation change over a 6-1/2-year period.

Overall, sedimentation rates were high over the time period that the scientists studied. Specifically, riverine and interior areas gained elevation over the time period studied. The fringe areas in all four river basins, however, lost elevation over the time period studied. The scientists also found that fringe and riverine zones were moderately **susceptible** to sea-level rise, with fringe zones being the most susceptible. The fringe zones are most susceptible to sea-level rise because they are closer to the sea and have the greatest amount of erosion. If the level of the water changes, it affects these areas more quickly.

Discussion

Understanding how sedimentation affects mangrove forests can help people who manage tropical forests make better decisions about how to use the land surrounding mangrove forests. In this study, harvesting had a negative effect on soil elevation. The less soil there is, the more susceptible an area is to rising sea levels. Scientists suggest that mangrove forests may need to be protected from nearby harvesting so that soil elevation is not negatively affected. The scientists in this study thought that this protection was particularly true for the fringe areas. These areas are more susceptible to sea-level rise and may not gain back the soil that would be lost during harvesting.

The scientists also found that continuous soil **deposition** is very important on these islands and helps with elevation levels relative to sea-level change. Continuous soil deposition means that through different processes such as weathering rock, soil is deposited in areas. This soil helps build the elevation of the area. Higher elevations protect the island from sea-level rise. Sea-level rise can greatly affect mangrove forests and other parts of the island ecosystem. Therefore, understanding soil deposition, elevation change, and sea-level rise helps scientists make the best recommendations for protecting the mangrove forests on these islands.

Reflection Section

- Why do you think harvesting of overstory trees may have affected the soil elevation?
- Why do you think fringe areas generally lost soil elevation over the time period studied?



Reflection Section

- Why is it important for tropical land managers to learn how best to manage the land around mangrove forests?
- Why is it important for people living on the islands to be concerned about rising sea levels?



Glossary

Accurate (ak yə rət): Free from error.

Aquifer (ak wə fər): A water-bearing layer of rock, sand, or gravel capable of absorbing water.

Atoll (a töl): A coral island consisting of a reef surrounding a lagoon.

Barrier island (bar ē ə r ī lənd): A long broad sandy island lying parallel to a shore that is built up by the action of waves, currents, and winds and that protects the shore from the effects of the ocean.

Backswamp (bak swamp): A wetland area that is not directly affected by wave energy.

Communal (kə myün əl): Shared by a group or community.

Contamination (kən tam ə nā shən): The act or process of making something harmful or unpleasant.

Debris (də brē): The accumulation of fragments of rock and wood.

Deposition (dep ə zish ən): The act or process of depositing. In this example, soil is deposited on the land from different processes like erosion and weathering.

Elevation (el ə vā shən): The height above sea-level.

Harvest (här vəst): The act or process of gathering in a crop or wood from a forest.

Instrument (in(t) strə mənt): A measuring device for determining the present value of a quantity under observation.

Land manager (land man ij ə r): A skilled individual who takes care of the land.

Matrilineal (ma trə li nē əl): Relating to family descent through mothers.

Navigation (nav ə gā shən): The science of getting ships, aircraft, or spacecraft from place to place.

Overstory (ō vər stōr ē): The layer of tree leaves and foliage in the tree canopy.

Peer review (pi(ə)r ri vyü): A process used for checking the work performed by one's equals (peers).

River basin (riv ə r bās ən): The land area drained by a river and its tributaries.

Sediment (sed ə mənt): Material deposited by wind, water, or glacier.

Sedimentation (sed ə mən tā shən): The act or process of depositing sediment.

Susceptible (sə sep tə bəl): Easily affected.

Tropics (träp iks): The region that surrounds the equator and goes from 23.5 degrees north latitude to 23.5 degrees south latitude.

Variable (ver ē ə bəl): Thing that can vary in number or amount.

Vertical (vərt i kəl): Going straight up or down from a surface.

Accented syllables are in **bold**. Definitions and marks are from <http://www.merriam-webster.com>.

Adapted from Krauss, K.W.; Cahoon, D.R.; Allen, J.A.; Ewel, K.C.; Lynch, J.C.; Cormier, N. 2010. Surface elevation change and susceptibility of different mangrove zones to sea-level rise on Pacific High Islands of Micronesia. *Ecosystems*. 13: 129–143.



Time Needed

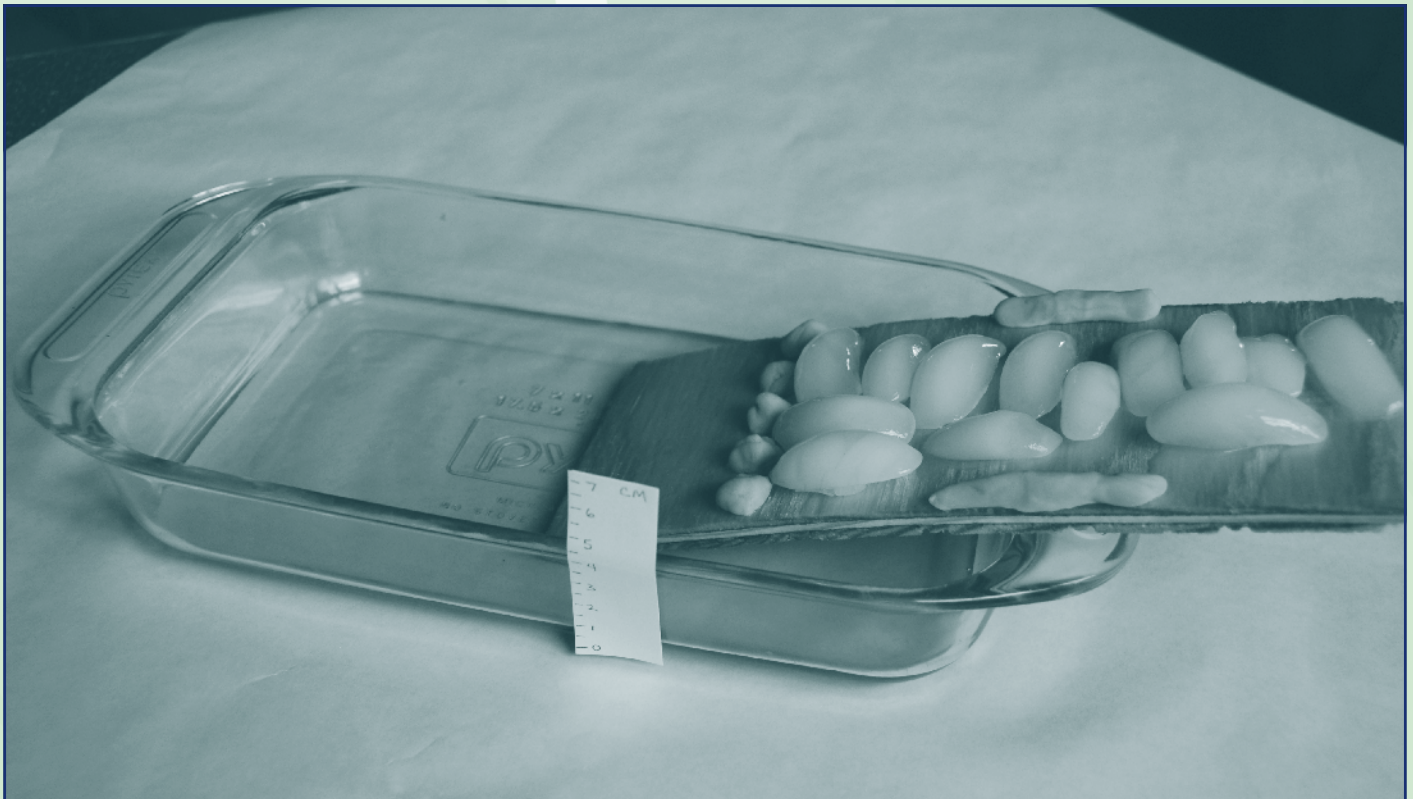
1.5 to 2 hours

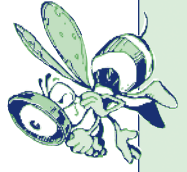
Materials

- Glass baking dish (7 x 11 inches).
- Piece of plywood, to fit partially inside the container at an angle (see picture), such as a 4.5-by-10-inch piece.
- Ruler.
- Ice cubes.
- Water.
- Small container of playdough or modeling clay.
- Permanent marker or dry erase marker.
- Blue food coloring.
- Masking tape (optional).

In this FACTivity, you will explore the idea of sea-level rise. This FACTivity has been adapted from the Digital Library for Earth Systems (DLESE) and the Deep Earth Academy at the Consortium for Ocean Leadership. For more information about similar activities and extensions, please visit <http://www.teachingboxes.org/sealevel/lessons/lesson2.jsp> and http://oceandrilling.coe.tamu.edu/curriculum/Sea_Level/Ice_Volume/teachers_notes.html.

All the world's ice can be divided into two types: sea ice (icebergs) and sheet ice (ice on land). Although both types of ice are at risk of melting if the average global temperature of the Earth increases, they have very different effects on the global sea level. In this activity, you will investigate what effect land ice will have on sea level.





Visit <http://www.teachingboxes.org/sealevel/lessons/lesson2.jsp>

to find an activity that illustrates what happens when icebergs melt. Students can then compare and contrast these two activities and observe how each type of melting may or may not affect the amount that sea level will rise.

In addition, an excellent short video simulates these two activities can be found at http://oce-andrilling.coe.tamu.edu/curriculum/sea_level/ice_volume/activity.html. The video reinforces concepts learned after the students complete the FACTivity.

Methods

1. Use the ruler to mark measurements every 2 millimeters from the bottom to the top of the glass dish so that you can measure any change in water elevation. You may do this on masking tape and then put the tape on the outside of the container or you may also try dry eraser markers on the outside of the dish.
2. Place the wood at an angle in the dish (see picture, opposite page).
3. Fill the dish with enough water to cover the bottom of the dish. Mark down this measurement under the "Start" box in the table provided.
4. Put about 3 drops of blue food coloring in the water.
5. Place playdough or modeling clay in a line just before the water. This line of playdough will keep the ice from sliding down as it melts. Make sure there are small open spaces in between each ball of playdough so the water can move through (see picture).
6. Place the bowl out into the sunlight.
7. Fill the board with ice cubes (see picture).
8. Re-check and record the water level and the amount of ice remaining every 20 minutes throughout the session.

Results and Discussion

Record your observations of the water level in the table below:

	Start	20 minutes	40 minutes	60 minutes	80 minutes	100 minutes	120 minutes
Water level							

1. How did the water level in the bowl change as the ice melted?
2. How can you explain your observation in question 1?

Unity in Diversity

The Federated States of Micronesia (FSM) is made up of 607 islands. These islands are located in the Central Pacific Ocean (see figure 3 in the article). Four states make up the FSM: Pohnpei, Kosrae, Chuuk, and Yap. The total population of the FSM is approximately 100,000, and the official language is English. People living on these islands, however, speak eight major native languages: Yapese, Ulithian, Woleaian, Chuukese, Pohnpeian, Kosraean, Nukuoro, and Kapingamarangi. Because large expanses of water separate the islands, island groups have evolved some distinct cultural traditions. Several cultural traditions, however, are similar across the islands.

One cultural tradition that is similar across the islands is the maintenance of strong family bonds through the large extended family. Another common cultural tradition is the importance of clans or family groups. Today, however, the importance of clans has decreased for the island groups of Kosrae. People in Pohnpei, however, still emphasize **matrilineal** clans.

Micronesian people rely heavily on fishing and farming. Farming is focused primarily on tree crops like breadfruit, coconut, banana, and citrus. Root crops like yam, sweet potato, tapioca, and taro are also important. The coconut tree is a vital crop for survival on isolated islands. This tree is used to provide nourishment from the water, milk, and oil; the husk is used for fuel to cook food and make rope for building homes and canoes; and the leaves are woven for mats and roofing material. **Communal** labor and sharing are important and the tradition of giving gifts and respect to tribal leaders remains.

Even though the states have cultural practices that link people across Micronesia, each state and even island can have different customs and traditions. The people of Yap dress in customary clothing. Women wear grass skirts or fabric hand woven from banana fibers called a “lavalava” and men wear a type of loincloth called a “thu.” Fishing, farming, sailing, and weaving are a part of daily life. Dancing is an important cultural tradition. The dances tell their history and legends and are a form of entertainment. Children are encouraged at an early age to learn these special dances.

The people of Yap are also famous for their stone money. This money was carved from stone in distant islands and brought to Yap through treacherous journeys by traditional canoes. The stones are so large that a hole had to be carved in the middle of the stone. This hole enabled a wooden post to be inserted in the middle that would be held by multiple people to carry it. Today, the traditional stone money lines the pathways in front of the village cultural houses. Here, they are held just as money would be held in a bank. Each stone holds a history that impacts its value, and the owner is known by everyone in the village.



Mr. Jermy Uowolo displays traditional Yapese tattoos. He and his sons Mykah (left) and Jayden (right) are wearing thus. The striped belts are made from hand-woven fabric called lavalava.” *Photo courtesy of Amanda Uowolo.*

The stone money is still used today for important exchanges of high cultural value.

In the state of Chuuk, woodcarvers make beautiful masks and items for use in the home and sea craft, among other objects. The most accomplished wood

carvers also build canoes and boats high in the hills of inner islands and then bring these boats down to the sea when they are nearly complete. It is common to see women on these islands waist deep in mangrove forests looking for delicacies among the sea life. The women use open-hearth fires to cook daily meals.

In Pohnpei, communities will come together to build a new boathouse or just to complete daily chores. The people here are known for their energetic cultural dances. They use these dances to pass on tradition, language, and family unity.

In Kosrae, native people practice singing and chanting as cultural traditions. Weaving, woodcarving, canoebuilding, and housebuilding are important to the people of Kosrae.

A special relationship exists between Hawaiians interested in traditional ways and the FSM. Before **navigation** instruments were available, Polynesians made ocean voyages across wide expanses of open ocean. Some of these Polynesians settled on the islands of Micronesia and some on the islands of Hawai'i. Polynesian sailors used the horizon, stars, weather, wind and wave patterns, the feel of ocean swells, clouds, ocean and sky colors, and wildlife movements to keep track of their location, direction, and speed. These sailing techniques were passed along in word and song and were often kept secret.



Traditional canoe house on the Yapese island of Fais, which has no electricity and no cars. *Photo courtesy of Amanda Uowolo.*

By 1975, there were no Hawaiians who knew these ancient navigation techniques. At that time, Master Navigator Mau Pailug of the FSM was only one of six navigators who still used these techniques. Of the six, only Mau was willing to share his knowledge with the Hawaiians.

He was asked by the Polynesian Voyaging Society to teach them how to navigate in the ancient manner. Mau's willingness to share this knowledge helped to increase pride in traditional Hawaiian and Polynesian culture. This pride has led to a growing interest in voyaging, canoe building, and noninstrument navigation that unites the Pacific Islands.

For more information, visit <http://visit:fsm.org> or <http://traveltips.usatoday.com/micronesi:culture:11238.html>.

For a lesson plan on noninstrument navigation, visit: http://www.sciencebuddies.org/science-fair-projects/project_ideas/Astro_p008.shtml. A computer and Internet connection is required for this lesson.

Additional Web Resources

National Geographic's Mangrove Page:
<http://ngm.nationalgeographic.com/2007/02/mangroves/warne:text>

Smithsonian Institution Ocean Portal Site on Mangroves:
<http://ocean.si.edu/ocean:life:ecosystems/mangroves>

History of the Polynesian Voyaging Society:
http://www.pvs-hawaii.com/about_pvshistory.htm

Using Polynesian non-instrument navigation:
<http://www.pvs-hawaii.com/navigation/summary.htm>

National Education Standards

National Science Education Standard	Where and How the Standard Is Addressed
Abilities Necessary To Do Scientific Inquiry	Thinking About Science: Measurements and instruments used to measure. Introduction Reflection Section: State the research question. Methods: Technology, observation, measurement. Findings: Evidence. Findings Reflection Section: Drawing conclusions from data.
Understandings About Scientific Inquiry	Thinking About Science: The importance of measurement and using instruments to make accurate measurements. Introduction Reflection Section: Hypotheses and research questions. Number Crunches: Math is important in scientific inquiry. Methods: Implementing an experiment, instruments used to take measurements. Methods Reflection Section: Understanding the importance of using more than one test site, understanding the importance of recording observations, understanding the importance of gathering data over different lengths of time. Discussion Reflection Section: Implications and further study.
Structure and Function in Living Systems	Introduction: Structure and function of mangrove forests.
Regulation and Behavior	Introduction, Findings, and Discussion: Importance of mangrove forests and effects of sea-level rise and sedimentation on mangrove forests.
Populations and Ecosystems	Introduction: Importance of mangrove forests in the ecosystem. Method, Findings, and Discussion: How soil sedimentation helps stabilize mangrove forest areas.
Diversity and Adaptation of Organisms	Introduction: Importance of mangrove forests.
Structure of Earth System	Thinking About the Environment: Sediment formation. Methods: Sedimentation, changes in soil elevation, sea-level rise.
Populations, Resources, and Environments	What is sea-level rise? Sea-level rise. Findings: Harvesting.
Science and Technology in Society	Methods: Technology used to study sediment elevation change and sea-level rise. Findings and Discussion: Answers to scientists' research question and implications of those findings.

Understandings About Science and Technology	Methods: Using technology to measure sediment change over time and sea-level rise.
Science as a Human Endeavor	Meet the Scientists: Personal stories. Thinking About Science, Introduction, and Introduction Reflection Section: What the scientists were interested in studying.
Nature Of Science	Thinking About Science: Measurement and scientific instruments. Introduction: The applied nature of science (solving a problem). Discussion: Implications and the application of science to solve problems.

National Curriculum Standards for Social Studies	Where and How the Standard Is Addressed
Culture	The Federated States of Micronesia cultural essay. Introduction and Introduction Reflection Section.
Time, Continuity, and Change	The Federated States of Micronesia cultural essay.
People, Places, and Environments	Thinking About the Environment. Introduction. Method. Findings. Discussion. The Federated States of Micronesia cultural essay. Figures 1, 2, 3, 4.
Individual Development and Identity	The Federated States of Micronesia cultural essay.
Production, Distribution, and Consumption	Introduction. Discussion.
Science, Technology, and Society	Meet the Scientists. Thinking About Science. Thinking About the Environment. Introduction. What Is Sea-level Rise sidebar. Methods. Findings. Discussion. FACTivity. The Federated States of Micronesia cultural essay.
Global Connections	The Federated States of Micronesia cultural essay.