My Sediments Exactly!

Can Mangrove Forest Sediments Keep up With Rising Sea Level?

Photo courtesy of J. B. Friday.

Meet the Scientists

USDA Forest Service photo courtesy of Richard MacKenzie.

◀ **Richard MacKenzie,** Ecologist: The most amazing thing I have ever seen was in a mangrove forest in the Philippines. The Philippines are islands in the western Pacific Ocean. It was nighttime and we were motoring up a creek through the mangroves in our little boat. All that was visible were the black shapes of the trees along the creek. We came around a bend, and there was a SINGLE tree entirely covered in fireflies. It looked like someone had wrapped thousands of strands of lights around every branch. It was amazing and of course, I could not get a picture of it.

The other aspect I really love about working in mangroves is all the different places to which I have traveled and all the friends I have made. It is fascinating to experience how different cultures live in and around the mangroves as well as how they use the mangrove trees. I feel like I learn more from them than they do from me as a scientist.

Lastly, I love doing research and setting up fun experiments to try to answer our questions. It is exciting to see the results after all the hard work that we do in the field (see additional biography information on page 10).

What Kinds of Scientists Did This Research?

Ecologist: This scientist studies the relationship of living things with their living and nonliving environment.

Forest, Soil, and Climate Scientist: This scientist studies many different aspects of the environment, including trees and forests, soils, and climate change and the effects of climate on Earth.

Photo courtesy of Joko Purbopuspito.

▲ **Joko Purbopuspito,** Forest, Soil, and Climate Scientist: My favorite science experience is doing something unusual and at the border of things. In the following three paragraphs, see if you can identify the borders at which I have worked. Each paragraph mentions a different type of border.

I studied the movement of **phosphorus (fäs f(ə-)rəs)** fertilizers to the roots of plants during the early 1980s. Phosphorous is an essential nutrient for plant growth that helps plants with photosynthesis, plant structure, and energy. In the early 1990s, I planted clove tree seedlings **hydroponically** (hī drə **pä** ni klē) to mimic the soil nutrient solution. When you plant a plant hydroponically, you grow the plants in a nutrient solution that may not include soil. Today people call this area the rhizosphere (**rī** zə sfir), or the border between soil and plant.

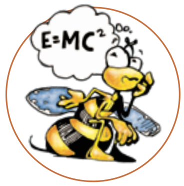
In the early 2000s, I studied the exchange of gases between soil, plants, and the atmosphere to learn about climate change.

Most recently, I worked at the Center for International Forestry Research in Indonesia. The Republic of Indonesia is a country located in Southeast Asia between the Indian and Pacific Oceans. There, I studied mangrove forests growing at the border of the ocean and the land. In this research, I investigated how much carbon was being stored in the forests. You will learn about some of this research in this article.

I love the tides a lot, and ocean fishing is my hobby. Through all my experiences, I learned a lot about myself and I am grateful for that knowledge.

Glossary words are bold and are defined on page 48.

Thinking About Science



Scientists often make comparisons as a part of their research. Many research questions ask about the similarities and differences between things. For example, the scientists in this research wanted to compare mangrove forests growing in different countries and conditions.

You are probably familiar with experimentation in science. In experimentation, one **variable** is exposed to a treatment in one situation. The same variable is not exposed to the treatment in another situation, called the control. Scientists then compare the experimental case with the control.

In nonexperimental research, scientists observe and measure one or more variables in natural settings that differ in one or more ways. In this research, for example, the scientists compared the same variables in mangrove forests located close to the ocean and away from the ocean, among other conditions.

Pretend that you want to compare the taste of different pizzas. In one comparison, you order pizza with the same list of toppings from two different restaurants. In another comparison, you make two similar pizzas at home, but you add pineapples to one of the pizzas. Otherwise, your homemade pizzas are the same. Which of these two comparisons is experimental? Which is more like the comparisons made in this research? Why?

Thinking About the Environment

For a moment, think about a time when you may have yelled loudly at your friend. Maybe you were angry because your friend did not invite you to play a game with them. Despite your feelings, yelling was probably not the best thing to do. On the other hand, let us say your friend was just about to step in front of an oncoming bicycle. You yelled to warn your friend of danger. In this situation, yelling was the best thing to do.

In this research, the scientists studied something that was helpful for an ecosystem. In other ecosystems, this same thing can do harm. The scientists studied the accumulation of sediment in mangrove forests that grow along ocean coastlines. Sediment consists of **organic** particles and minerals, such as sand and the remains of plants and animals. It contains solid materials that have been worn down by water and wind. When sediment moves into water bodies, it can be carried to a new location and deposited.

In some ecosystems, such as streams, rivers, or even coral reefs, too much sediment can cause cloudy water and may contain pollutants. In mangrove forests, however, healthy amounts of sediment are necessary to **sustain** the mangrove ecosystem. Mangroves are flooded by ocean tides 1-2 times a day depending on where they are located. As the water floods the mangroves, the roots and trunks slow the water down and any sediment that is suspended in the water settles out.

Sediment helps mangrove forests in many ways. Over the past century, sediment has helped mangrove forests to adjust to rising sea levels. When the sea level rises, the surface of the ocean gets higher. As sediment is deposited in mangrove forests, the forest floor also rises in height (**figure 1**). The mangrove forest can then maintain the height of its forest floor relative to the water height of the ocean.

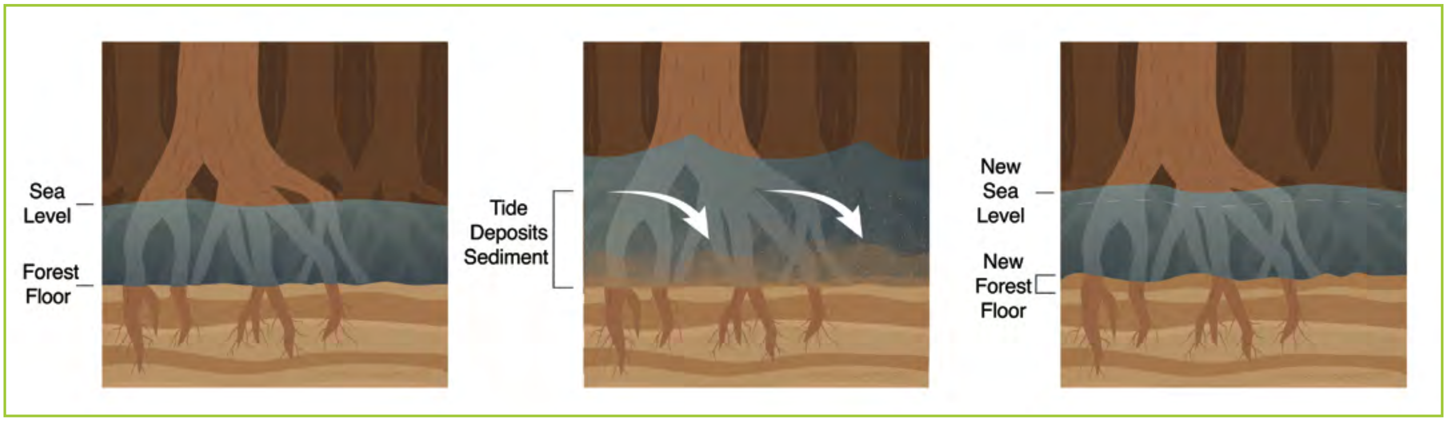


Figure 1. Sediment added to the forest floor (vertical accretion) helps mangrove forests adjust to rising sea level. FIND Outdoors illustration by Liz Sisk.

Introduction

Mangrove forests are found in tropical coastal areas worldwide (**figure 2**). Mangrove trees live in the intertidal zone. The intertidal zone is the area between low tide and high tide on or near the coast (**figure 3**, page 34). Mangrove trees have complex roots that live above ground and below the forest floor (**figures 4a–4e** and **figure 5**, pages 35 and 36).

Mangrove forests provide many **ecosystem services**. Mangrove forests reduce the impact of powerful waves generated by storms, such as typhoons and hurricanes. These storms can impact human and natural coastal communities. Mangrove forests provide places for fish, turtles, crabs, birds, amphibians, and many other animals to breed, raise their young, and live. Even Bengal tigers are found in the extensive mangrove forests of Sundarbans. Sundarbans is the largest continuous mangrove in the world and consists of both Bangladesh and India.

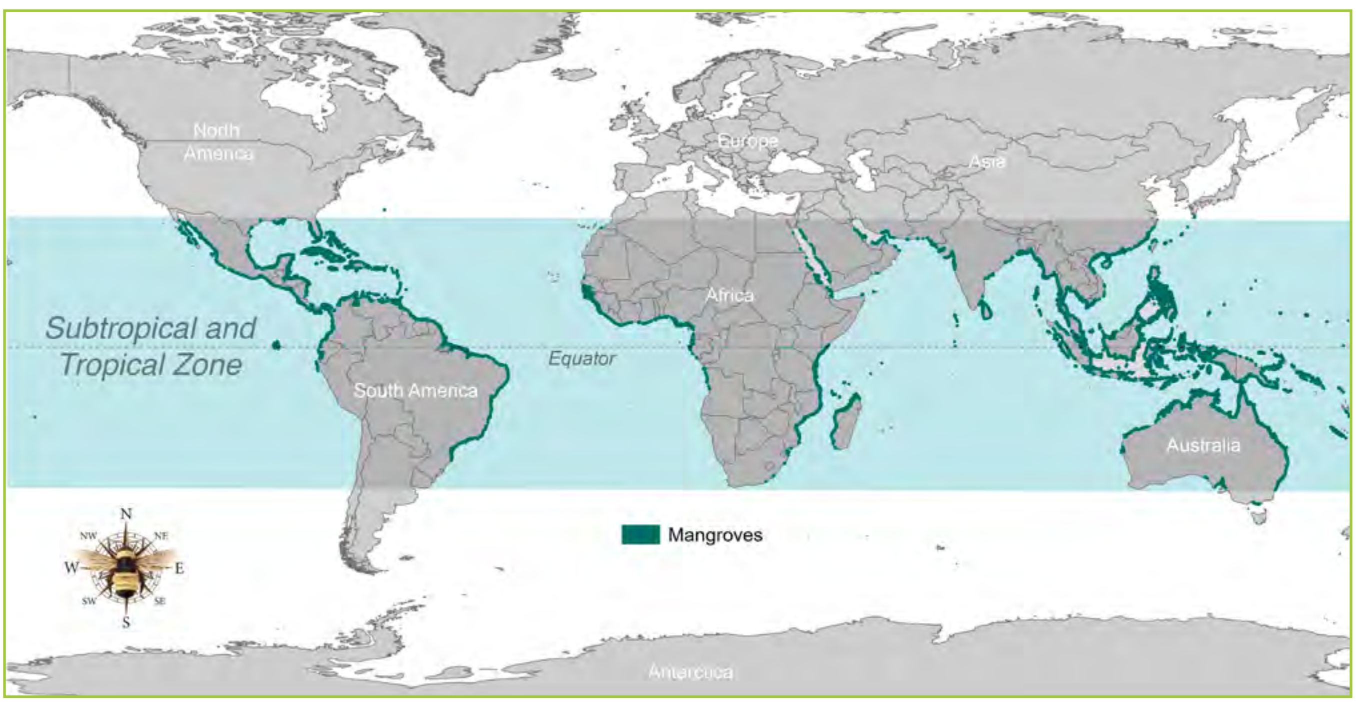


Figure 2. Mangrove forests are found in the tropical zone worldwide. The tropical zone is an area north and south of the Equator. FIND Outdoors map by Carey Burda.

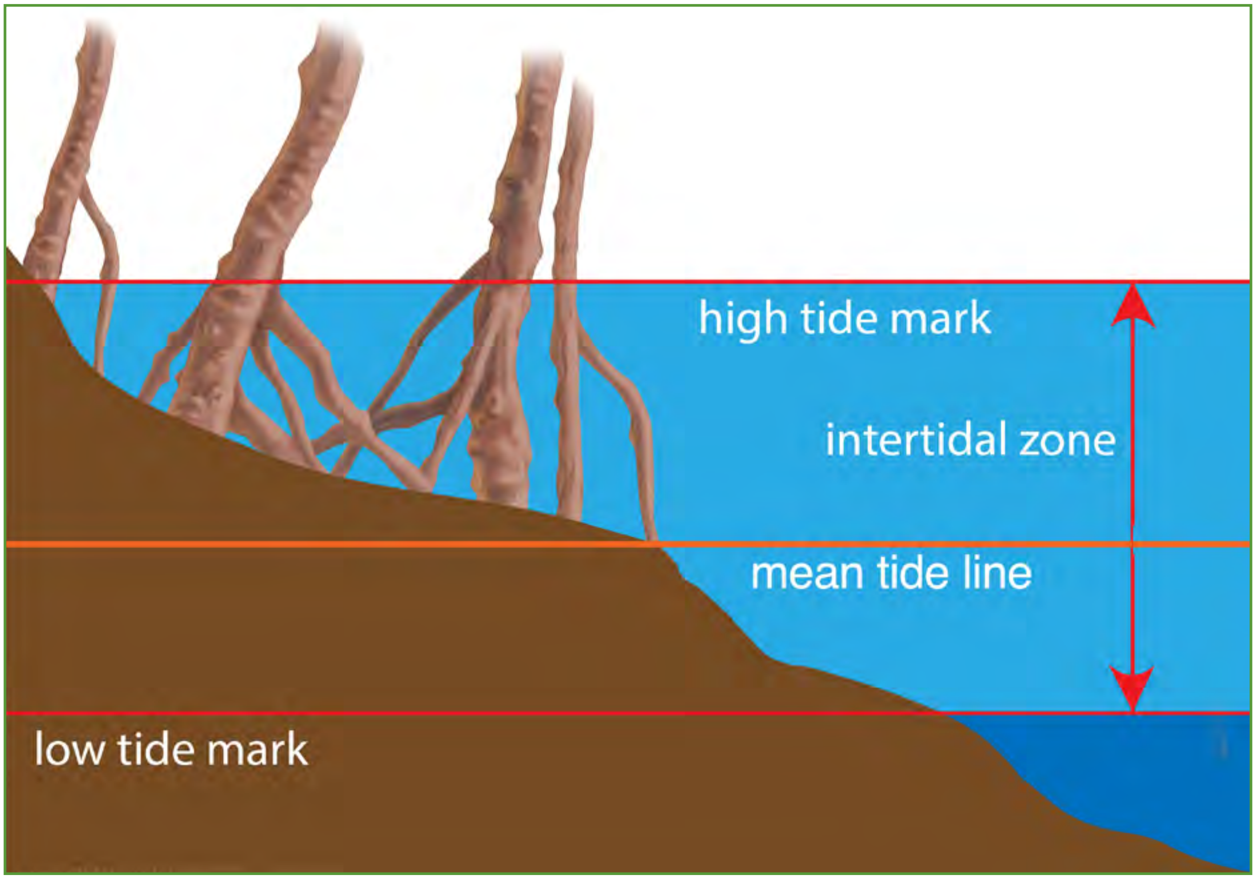


Figure 3. The intertidal zone is the zone between low tide and high tide. FIND Outdoors illustration by Megan Reeves.

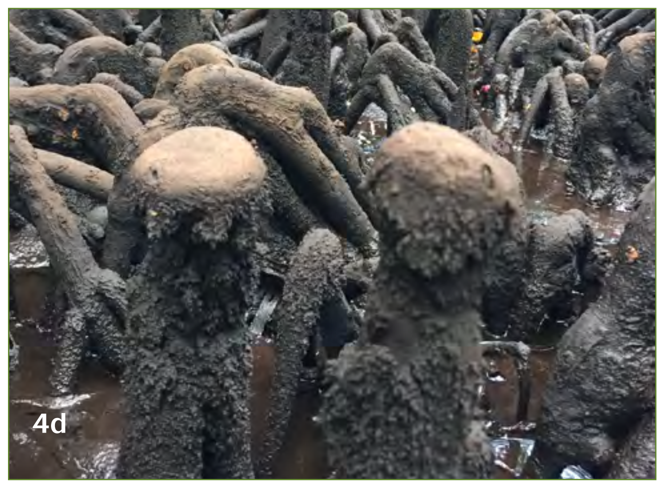
Mangrove forests improve water quality by filtering water and removing pollutants. Mangroves also remove massive amounts of carbon dioxide from the atmosphere and store it their trunks, branches, and roots, helping to protect against climate change. Mangroves store more carbon than any other forested ecosystem on Earth!

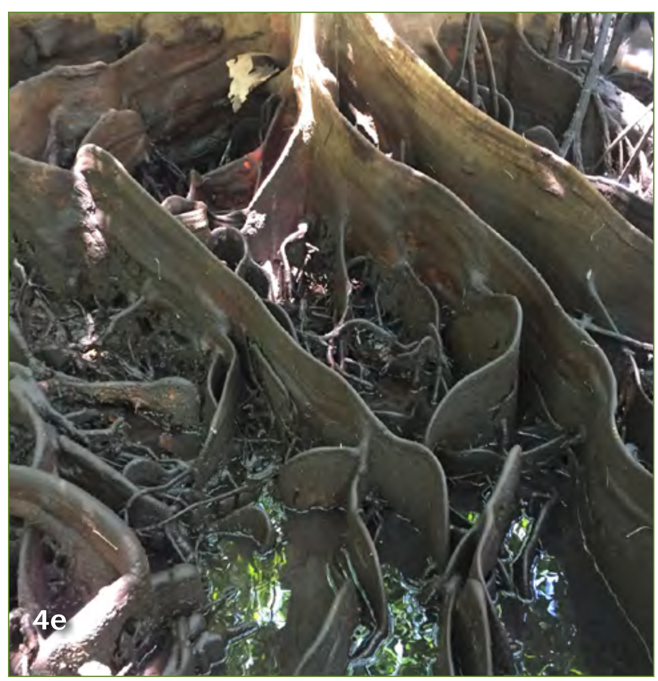
Rising sea level is one of the biggest threats to healthy mangrove ecosystems. Some research has suggested that mangroves can keep up with rising sea level through the accumulation of sediment on the mangrove forest floor and belowground root growth (see "Thinking About the Environment" and **figure 1**). When mangroves keep up with rising sea levels, the height of their forest floor rises at the same rate as the sea level. When sediments and roots accumulate in such a way as to add height to the forest floor, it is called vertical **accretion** (ə **krē** shən). However, as the rate of sea level rise continues to increase over time, scientists wonder if vertical accretion in mangrove forests can keep up with rising sea level.

The scientists in this study wanted to compare the accumulation of sediment on the forest floor, vertical accretion, and the amount of belowground carbon accumulation in different mangrove forests (**figure 6**, page 37).

Human activities, such as harvesting too many trees, and natural processes such as hurricanes, can result in **deforestation** of mangroves. When trees are removed, large amounts of the carbon that are stored within them may be released back to the atmosphere (**figure 7**, page 38). Increasing levels of carbon in the atmosphere is changing our climate. Therefore, protecting ecosystems that store carbon, such as mangrove forests, is important.

Mangrove forests with several different mangrove tree species have more diverse root structures than mangrove forests with only





Figures 4a–4e. Mangrove forests have a variety of complex root systems. 4a: Prop roots. 4b: Pneumatophore (nu̇ **ma** tə fȯr) roots. 4c: Spreading roots. 4d: Knee roots. 4e: Ribbon roots (or buttress roots). USDA Forest Service photos by Rich MacKenzie.

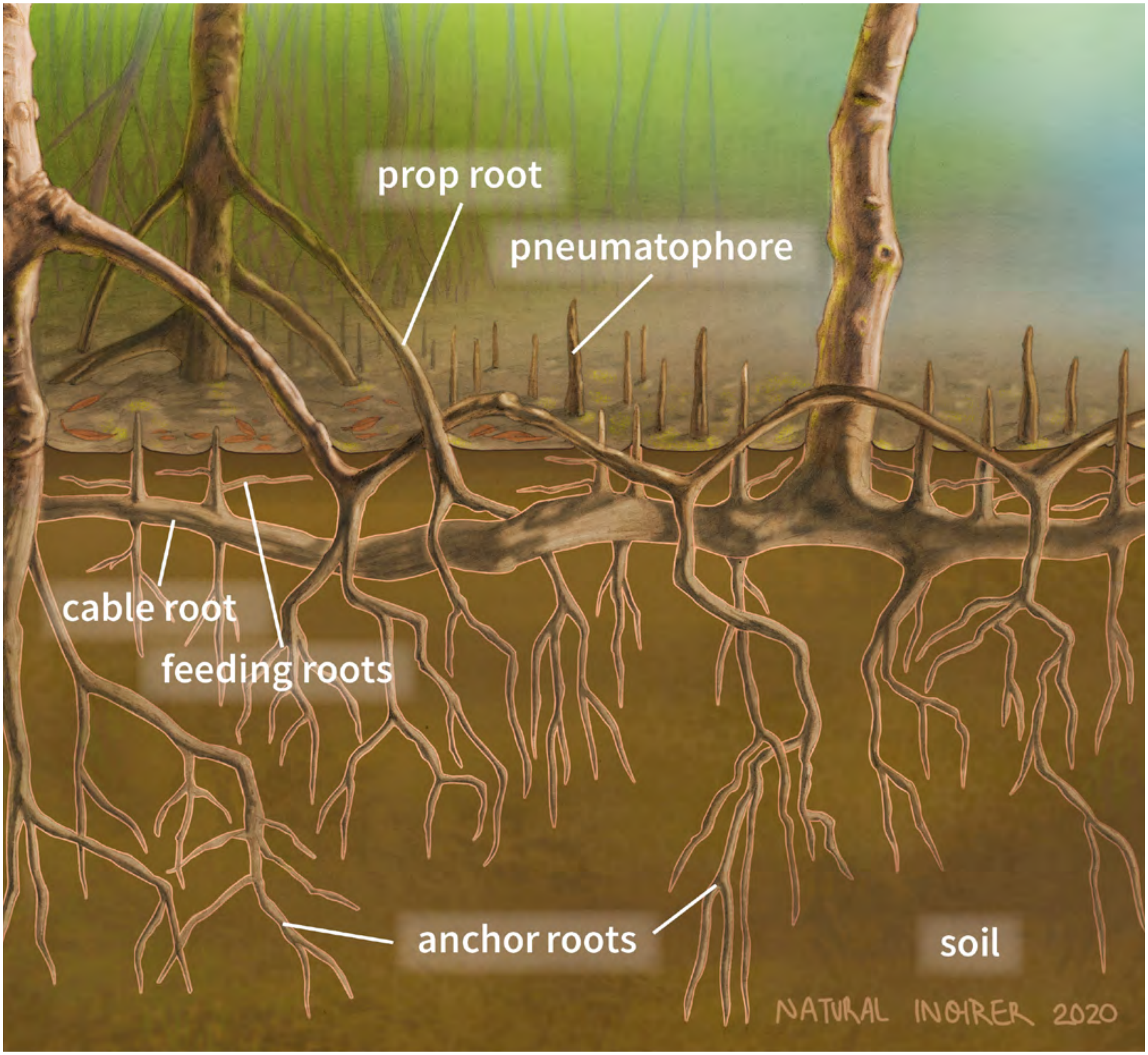


Figure 5. Mangrove forests have extensive underground root systems. FIND Outdoors illustration by Megan Reeves.

one species (see **figures 4a–4e**, page 35). More diverse root structures may contain more carbon and may trap and hold more sediment than less diverse root structures.

Mangroves impacted by bridges, roads, and other human structures may trap and hold less sediment than mangroves that are not impacted. These human-built structures may restrict the flow of water and sediment from rivers or the ocean into mangrove forests.

The rate of vertical accretion may also be impacted by the amount of sediment carried into a mangrove forest by tides or by inland rivers. Therefore, the **proximity** of a mangrove forest to the ocean may affect the amount of sediment that is deposited on the mangrove forest floor, vertical accretion, and the accumulation of underground carbon (**figures 8** and **9**, pages 38 and 39).

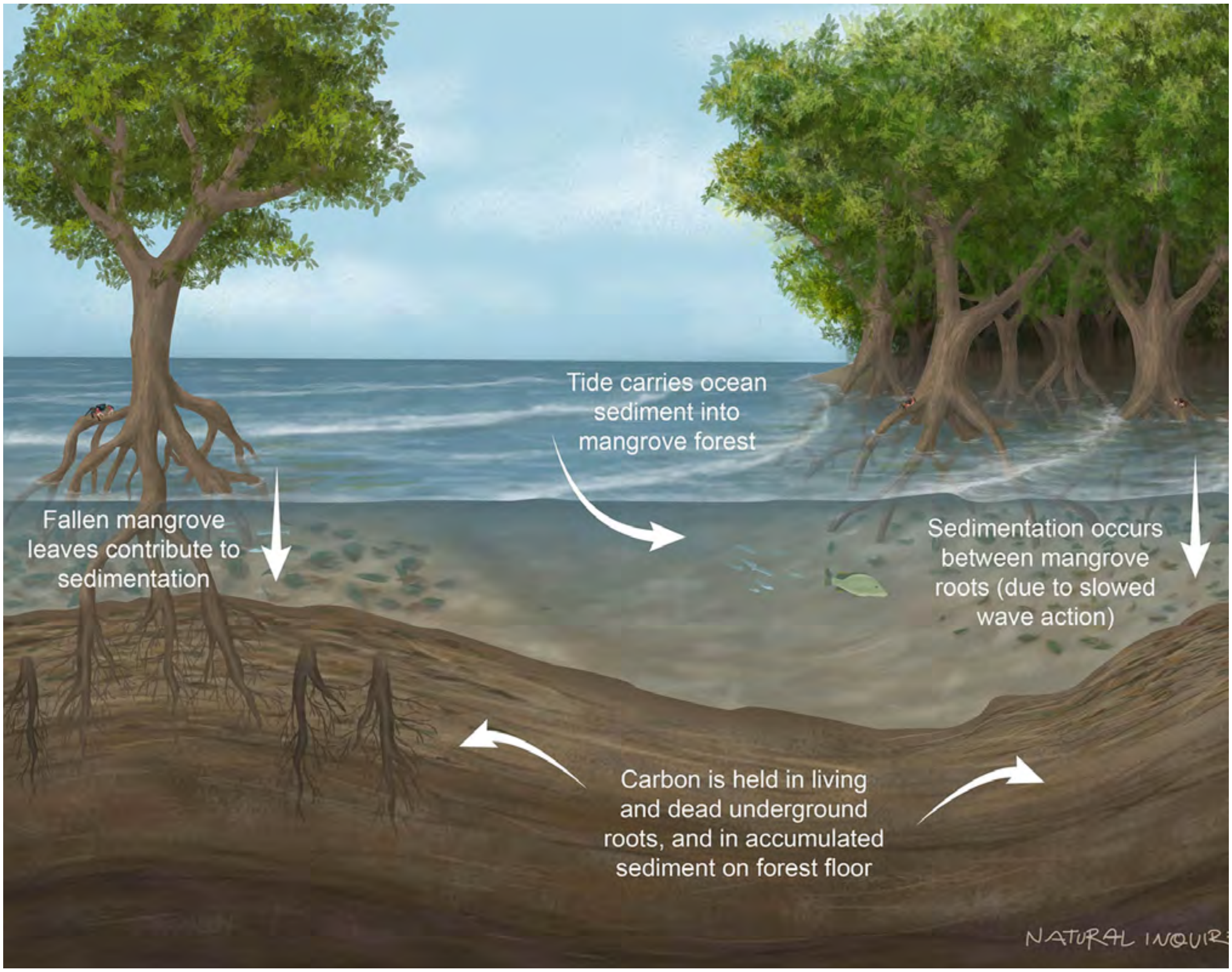


Figure 6. Carbon accumulates in mangrove sediments on the forest floor and in the mangrove forest soil. FIND Outdoors illustration by Liz Sisk.

When mangrove forests are cut down, aboveground and belowground root growth stops. In addition, water and soil temperatures increase due to more sunlight. Warmer water and soil cause faster **decomposition** of roots and the forest floor starts to collapse. In addition, as trees are removed, the carbon is also removed. The loss of belowground roots also causes more carbon loss (see **figure 6**). To stop or reverse carbon loss in tropical coastal ecosystems, new mangrove forests must grow. Mangrove forests may grow back naturally on their own over time, or people can purposely plant new mangrove forests.

The scientists in this study wanted to identify which mangrove forests growing in the conditions described previously were keeping up with sea level rise. To identify these mangroves, the scientists compared mangrove forests growing under the different conditions listed previously.

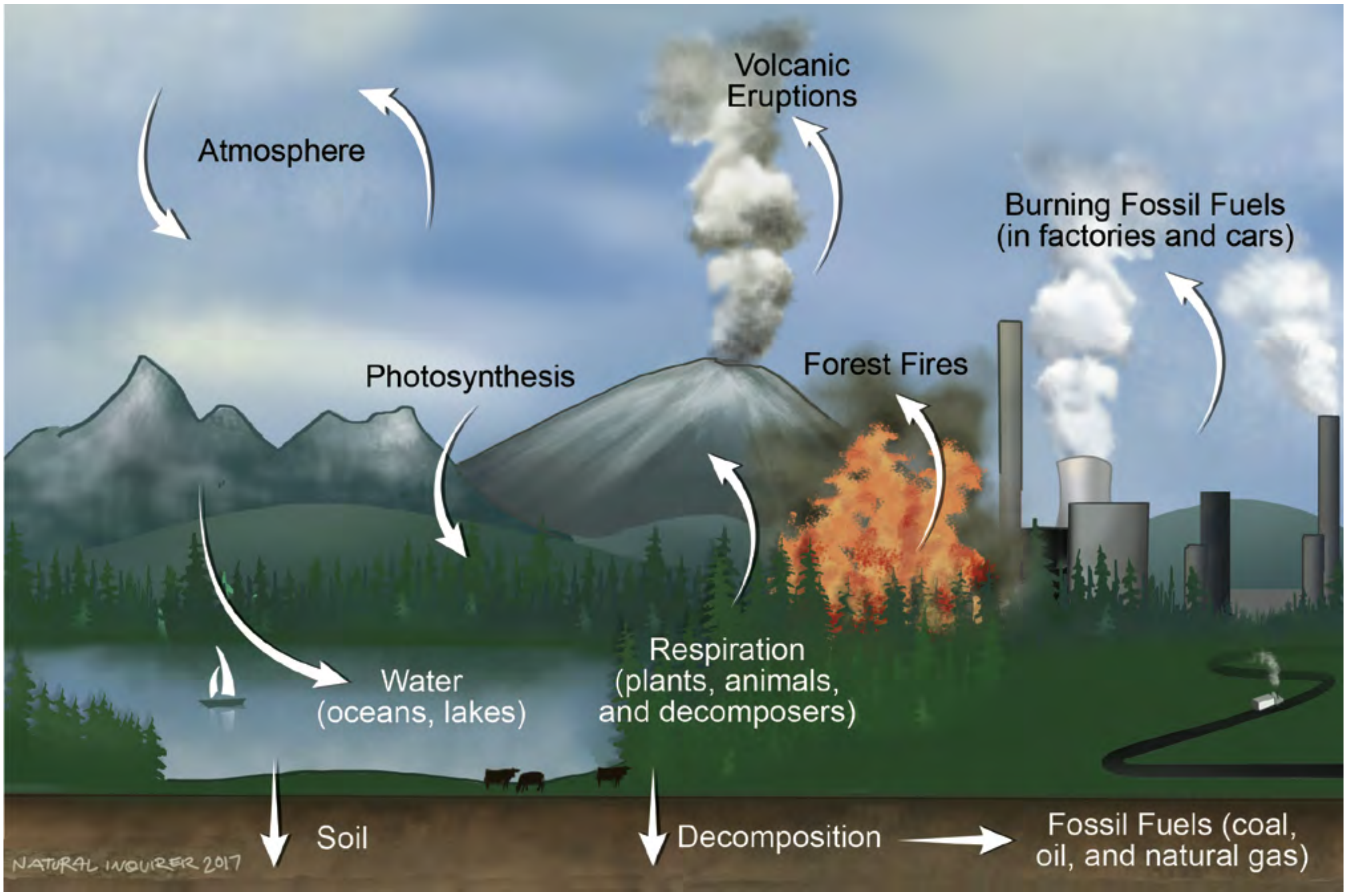


Figure 7. The carbon cycle. FIND Outdoors illustration by Stephanie Pfeiffer Rossow.

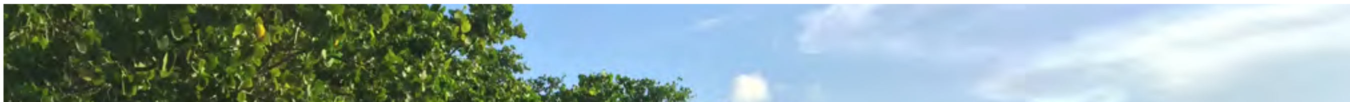


Figure 8. This mangrove forest is located by the ocean. USDA Forest Service photo by Rich MacKenzie.

Figure 9. This mangrove forest is located within the tidal zone, but it is not by the ocean. Photo courtesy of Babs McDonald.

Reflection Section

- Based on what you read in the "Introduction," what mangrove forest conditions do you think the scientists studied? (Hint: Reread the last five paragraphs in the "Introduction.")
- Why is it important to identify the best conditions for mangrove forests to keep up with sea level rise?

Methods

The scientists studied mangrove forests on Babeldaob **(bä bəl daub)** Island in the Republic of Palau **(pə laů)** and in Vietnam (**figures 10, 11,** and **12**). The scientists established six mangrove study sites in Palau and two in Vietnam (**figures 13a** and **13b**).

The scientists studied mangrove forests with different conditions and characteristics (**table 1**, page 42). Unlike the mangrove forests in Palau, the mangrove forests in Vietnam had been harmed between 1961 and 1971 by a chemical used to eliminate forest cover. Much of Vietnam's southern mangrove forests were destroyed or severely damaged by this chemical use. Therefore, the scientists studied mangrove forests in Vietnam that were either purposely regrown or grew back naturally.

Within each of the study site locations, the scientists established study plots to measure mangrove forest variables, including the **density** of the trees, the types of tree species, and the

Figure 10. Mangrove forest in Palau. USDA Forest Service photo by Rich MacKenzie.

Figure 11. Mangrove forest in Vietnam. USDA Forest Service photo by Rich MacKenzie.

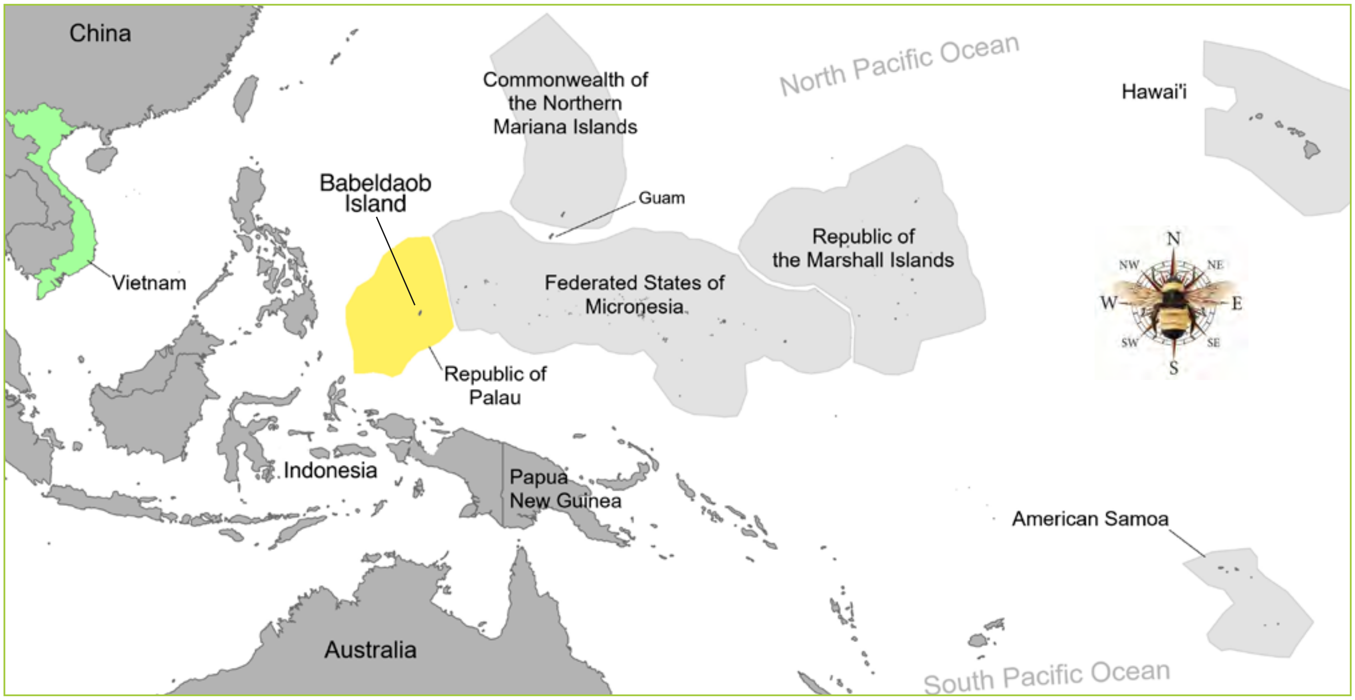
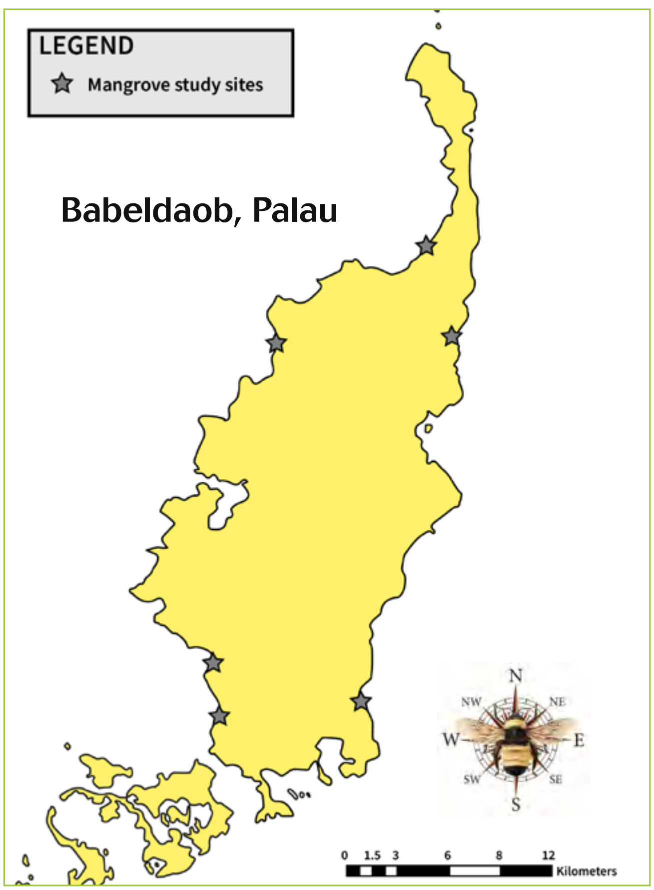
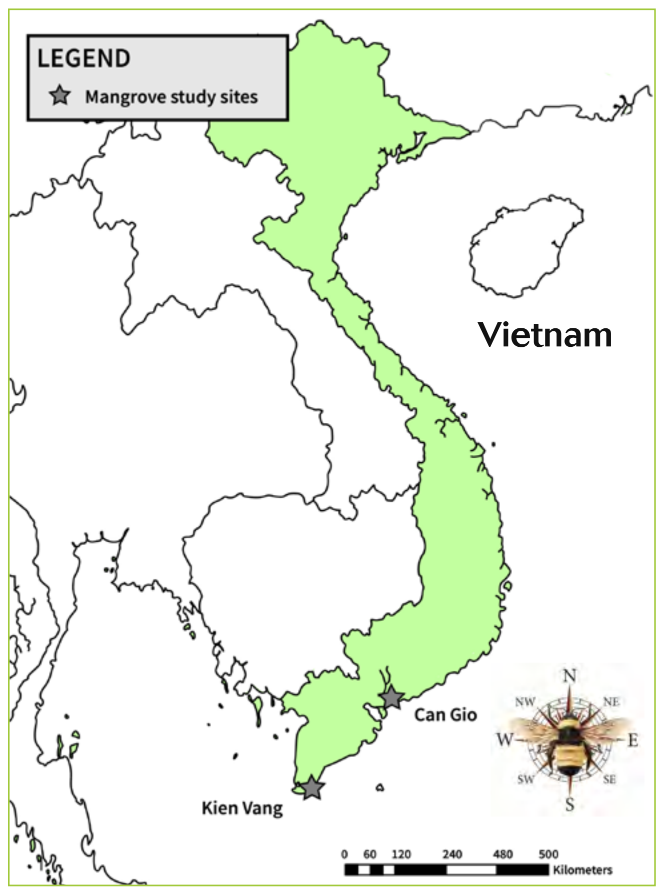


Figure 12. Babeldaob Island in the Republic of Palau, and Vietnam. FIND Outdoors map by Carey Burda.





Figures 13a and 13b. Mangrove study site locations on Babeldaob Island in Palau, and in southern Vietnam. FIND Outdoors maps by Megan Reeves.

amount of wood in the forest (**table 2** and **figure 14**). Based on the data collected in each study plot, the scientists estimated these values for the whole mangrove forest. The scientists also collected **sample** cores of the mangrove forest soil from these study plots. After each core was pulled, the scientists cut the core into sections that were either 2 centimeters (cm) or 4 cm long. These sections were labeled and taken to the laboratory for analysis.

Table 1. Mangroves with different conditions were compared.

Mangrove condition	Palau	Vietnam
One **dominant** mangrove tree species	✔	✔
Several tree species	✔	
Human-built structures (a paved highway) nearby	✔	
No human-built structures nearby	✔	
Near the ocean	✔	✔
Not near the ocean	✔	✔
Naturally regrown		✔
Purposely planted		✔

Table 2. Characteristics of mangrove forest plots studied in Palau and Vietnam.

	Distance from the ocean		Total number of mangrove sites studied
	Close to ocean	Away from ocean	
Palau	15 meters	375 meters	11
Vietnam	15 meters	150 meters	8

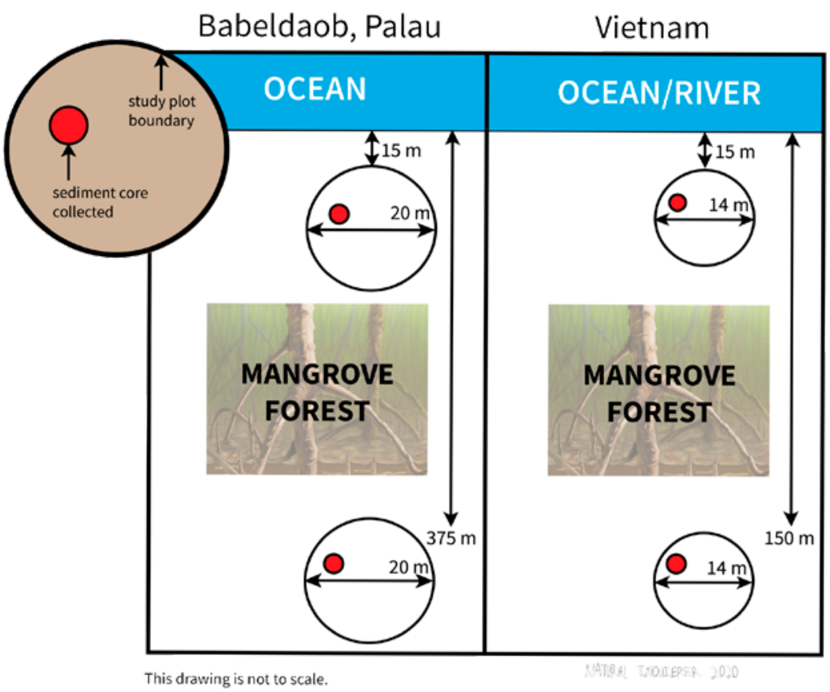
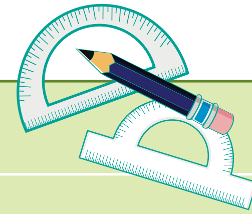


Figure 14. Study plots were established in the study site locations (see table 1). The measurements were taken in meters (m). Mangrove tree variables were measured in each of these 19 study plots.
FIND Outdoors illustration by Megan Reeves.

Number Crunch



- Convert "Distance from the ocean" in table 2 from meters (m) to feet (ft).

  (Hint: Multiply the number of meters by 3.281 to calculate the number of feet.)

What Is a Core Sample?

When scientists want to learn about the soil, they may use a core instrument to gather a sample. This instrument may be a soil probe, a core sampler, or an auger. The resulting core sample is half of a cylinder.

FIND Outdoors photo by Jessica Nickelsen.

The scientists collect soil samples in mangrove forests in Vietnam. USDA Forest Service photo.

The scientists collect soil samples. Look carefully and you can see the scientists measuring and cutting the soil samples into sections. USDA Forest Service photos by Rich MacKenzie.

The scientists calculated sedimentation rate per year, vertical accretion rate per year, and how much carbon had accumulated in the soil every year (**table 3** and **figure 15**). They calculated this information from the core samples of sediment. Sedimentation rate is calculated from the amount of sediment deposited each year. Compare this with vertical accretion rate, which is calculated from the height of the forest floor each year. These two values are related but are not necessarily the same. Carbon accumulation is the additional amount of carbon stored in the soil over a year's time. To learn how scientists determine the age of sediment, read "Bee Challenged!" at the end of this "Methods" section.

Table 3. Data collected by the scientists. Carbon was measured in a metric weight measure called grams. One gram is equal to 1/1000 of a kilogram, and 28.35 grams equals 1 ounce.

What was calculated from the sediment cores	Unit of measurement
Sedimentation rates per year	Milligrams per square centimeter of soil
Vertical accretion rates per year	Centimeters of soil
Carbon accumulation per year	Grams per square meter (m^2) of soil

Figure 15. A tennis ball weighs about 2 ounces or about 58 grams. FIND Outdoors illustration by Liz Sisk.

The scientists then used computer programs to compare the sediment sample core values with the different mangrove tree variables. Recall that these mangrove forest variables included an estimate of the density of the trees, the types of tree species, and the amount of wood in the mangrove forest. The scientists also compared these values with the different conditions existing in mangrove forests of Palau and Vietnam (see **table 1**, page 42).

The scientists then compared the vertical accretion rates with the amount of measured sea level rise in Palau and Vietnam. The amount of sea level rise is measured by tide gauge instruments.

Reflection Section

- Look at table 1. What kind of impacts might human-built structures, such as a highway, have on mangrove forests?
- If the scientists discovered that vertical accretion rates are not keeping up with sea level rise, what will happen to the water depth at high tide in these mangrove forests?

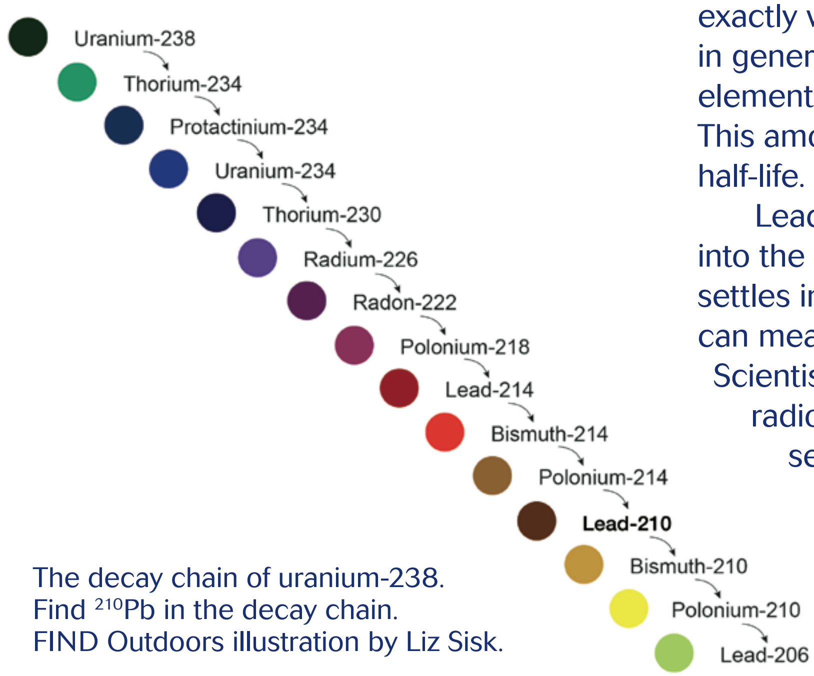
Bee Challenged!

How Do Scientists Determine the Age of Sediment?

Scientists calculate the age of sediment by analyzing the chemical elements present in the sediment. As you know, change is inevitable in the natural world. Chemicals are made up of atoms. When an atom's nucleus is unstable, it might lose a proton or neutron. This is called radioactive decay. When a proton is lost, the element becomes a different element. The new element is called a radionuclide (**rā** dē ō **nü** klīd).These radionuclides are naturally occurring and may also decay into another element.

In this study, the scientists calculated sediment accumulation per year. To calculate the age of the sediment, the scientists analyzed the radionuclide called lead 210, or ^{210}Pb. These ^{210}Pb radionuclides were once uranium. Although scientists cannot say exactly when an individual atom will decay, in general they know how long a chemical element's atom will exist before it decays. This amount of time is called the element's half-life. The half-life ^{210}Pb is 22.3 years.

Lead 210 falls from the atmosphere into the ocean or other water body, where it settles into the sediments below. Scientists can measure the radioactivity of ^{210}Pb. Scientists use this information about ^{210}Pb radioactivity to calculate the age of sediments found at different depths.



The decay chain of uranium-238.
Find ^{210}Pb in the decay chain.
FIND Outdoors illustration by Liz Sisk.

Findings

Sedimentation and vertical accretion rates were almost five times higher in mangrove forests of Vietnam than in Palau. Carbon accumulation rates in the soil were greater in mangroves located in Vietnam than in Palau, but the difference was not significant. In scientific research, the word "significant" has a special meaning. A significant finding is one that is not likely due to an error in measurement or to chance. In this research, the measured difference in carbon accumulation between mangroves in Palau and Vietnam may have occurred by chance or by a measurement error.

More diverse mangrove forests and forests with more trees experienced greater rates of sedimentation and vertical accretion (**table 4**).

Using instruments that measure the altitude, or height, of the ocean surface, an Australian government organization tracks sea level in Palau. This organization reported that the sea level in Palau rose 9 millimeters (mm) per year from 1993 to 2010. Compare this to a tide gauge in Palau. This gauge measured a 1.5 mm per year rise from 1969 to 2000. In Vietnam, coastal tide gauges measured a sea level rise of 3.1 mm per year.

The scientists converted vertical accretion rates to mm per year for Palau and Vietnam. They then compared the reported sea level rise in mm per year with the calculated vertical accretion in mm per year. The scientists found that both mangrove forests in Vietnam are keeping up with sea level rise. If the sea level is rising 9 mm per year in Palau, only 1 of the 11 mangroves in Palau is keeping up with sea level rise. If the sea level is rising 1.5 mm per year in Palau, all 11 mangroves are keeping up with sea level rise.

Table 4. Vertical accretion, sediment accumulation, and carbon accumulation under different mangrove forest conditions.

	Vertical accretion		Sediment accumulation		Carbon accumulation in soil	
	Palau	Vietnam	Palau	Vietnam	Palau	Vietnam
Human-built structures	Slightly lower with structures		No difference		No difference	
Proximity to ocean	2X higher near ocean	No difference	2X higher near ocean	No difference	No difference	No difference
Planted or naturally restored		No difference		Higher in naturally restored		Higher in naturally restored

Reflection Section

- Recall that carbon accumulation rates were greater in the Vietnamese mangroves than the Palauan mangroves, but the difference was not significant. In your own words, describe the difference in carbon accumulation rates in Vietnam and Palau.
- Consider the measurements of yearly sea level rise in Palau. One source reported a rise of 9 mm per year. Another source reported a rise of 1.5 mm per year. Do you think the scientists were correct in reporting the comparison of vertical accretion with sea level rise using both estimates? Why or why not?

Discussion

Depending on which measure of sea level rise is used for Palau, mangroves in Palau and Vietnam appear to be keeping up with sea level rise. As the rate of sea level rise is expected to increase, however, it is unknown if mangrove forests will continue to keep up in the future.

One of the most important differences between mangrove forests in Vietnam and Palau is the diversity of tree species. Vietnamese mangrove forests were more diverse with 35 tree species as compared to Palau's 18 tree species. The scientists found that more diverse mangrove forests experienced greater rates of sedimentation and vertical accretion rates. This finding is important to consider as governments have been recently replacing once diverse mangrove forests with mangrove forests of a single tree species.

Reflection Section

- In the first Reflection Section question of the Introduction, you answered the question: "Why is it important to identify the best conditions for mangrove forests to keep up with sea level rise?" Now that you have completed the article, what would you recommend are important conditions to conserve the health of mangrove forests so they can keep up with sea level rise?
- Diversity is an important concept and characteristic of mangrove forests. Identify another ecosystem or situation that benefits from diversity. Describe what is diverse and how the ecosystem or situation benefits from the diversity.

Adapted from MacKenzie, R.A.; Foulk, P.B.; Klump, J.V.; Weckerly, K.; Purbospito, J.; Murdiyarso, D.; Donato, D.C.; Nam, V.N. 2016. Sedimentation and belowground carbon accumulation rates in mangrove forests that differ in diversity and land use: a tale of two mangroves. Wetlands Ecology and Management. 24(2): 245–261. https://doi.org/10.1007/s11273-016-9481-3.

Glossary

accretion (ə **krē** shən): The increase of land by the action of natural forces.

decomposition (dē kəm pō **zi** shən): The act or process of breaking up, as by decaying or rotting.

deforestation (**dē** fȯ rə **stā** shən): The action or process of clearing of forests.

density (**den(t)** sə tē): The amount of matter in a given space.

ecosystem service (**ē** kə **sis** təm **sər** vəs): Any of the various benefits provided by plants, animals, and the communities they form.

organic (ȯr **ga** nik): Related to or coming from living organisms

proximity (prak **si** mə tē): The quality or state of being physically close.

sample (**sam** pəl): A small subset group, representative of the entire group.

sedimentation (**se** də mən **tā** shən): The process of depositing soil and other particles carried by wind or water.

sustain (sə **stān**): To keep up or maintain.

variable (**ver** ē ə bəl): A factor, trait, or condition that can be changed or controlled.

*Accented syllables are in **bold**. Marks and definitions are from http://www.merriam-webster.com.*
Definitions are limited to the word's use in the article.

FACTivity

Comparing Coastal Ecosystems

Time Needed

1 class period

Materials

- A blank piece of paper and a pencil.
- The poem on page 51.
- (Optional: Access to the library or the Internet)

The question you will answer in this FACTivity is: How do mangrove forests compare with salt marshes?

Background

The scientists in this research compared tropical mangrove forests in the countries of Palau and Vietnam. They also compared conditions in which these forests were growing, and they compared vertical accretion rate with the rate of sea level rise. Now it is your turn to compare! In this FACTivity, you will compare mangrove forests with another coastal ecosystem. This ecosystem is called a salt marsh. Salt marshes are found in North America on every United States coast, including Alaska and Hawai'i. Extensive salt marshes are found on the Gulf Coast and the eastern coast from Maine to Florida.

First review this information about salt marshes. You may want to do additional research in the library or online to learn more about salt marshes.

Adapted from the National Oceanic and Atmospheric Administration, https://oceanservice.noaa.gov/facts/saltmarsh.html:

> Salt marshes are coastal wetlands that are flooded and drained by salt water brought in by the tides (**figure 16**). They are marshy because the soil may be composed of deep mud and peat. Peat is made of decomposing plant matter that is often several feet thick. Peat is waterlogged, root-filled, and very spongy. Because salt marshes are frequently submerged by the tides and contain a lot of decomposing plant material, oxygen levels in the peat can be extremely low.
>
> Salt marshes occur worldwide, particularly in middle to high latitudes. Latitude is the distance north and south of the equator. Middle and high latitudes occur north and south of the tropical zone. Salt marshes thrive along protected shorelines.
>
> Salt marshes also protect shorelines from erosion by slowing wave action and trapping sediments. Salt marshes reduce flooding by slowing and absorbing rainwater and protect water quality by filtering runoff.

Figure 16. Salt marsh in Georgia. Photo by Babs McDonald.

FACTivity *continued*

Salt marshes do not contain forests. Instead, salt marshes are mostly made up of large areas of marsh grasses. At low tide, the marsh floor is visible (**figure 17**). The marsh floor is made up of sediment carried in by ocean tides and by inland rivers. At high tide, the marsh floor is submerged. At high tide, saltwater covers the salt marsh, and small holes in the grasses close to keep the saltwater from entering the plants (**figure 18**).

Figure 17. Salt marsh at low tide in Georgia. Photo by Babs McDonald.

Figure 18. Salt marsh at high tide in Georgia. Photo by Babs McDonald.

In 1878, Sidney Lanier wrote a poem called "The Marshes of Glynn." Glynn refers to Glynn County, Georgia, which has large areas of salt marsh. A small part of this 97-line poem is given below.

Farewell, my lord Sun!
The creeks overflow: a thousand rivulets run
'Twixt the roots of the sod; the blades of the marsh-grass stir;
Passeth a hurrying sound of wings that westward whirr;
Passeth, and all is still; and the currents cease to run;
And the sea and the marsh are one.
How still the plains of the waters be!
The tide is in his ecstasy.
The tide is at his highest height:
And it is night.

Read these lines carefully and answer the following questions. Write your answers on your paper using complete sentences, proper grammar, and correct spelling.

1. What part of the daily tide cycle are lines 2–9 describing?
2. How does this part of the daily cycle of a saltmarsh compare with the daily cycle of a mangrove forest? What are the similarities? What do you think are the differences?
3. In lines 2 and 3, compare this salt marsh with a mangrove forest.
4. In line 4, what do you think is happening in the salt marsh? Be as descriptive as possible.
5. In lines 5 and 6, compare this salt marsh with a mangrove forest.
6. In lines 5 through 9, what do you think is happening in the salt marsh? Be as descriptive as possible.
7. These lines are describing evening and nighttime in a salt marsh. Does this same thing happen at any other time of the day? How do you know?

Your teacher will hold a class discussion to explore your comparisons.

Another FACTivity

Common Core Connection

Now, you will be like Sidney Lanier and write your own poem. Quickly review the article you just read and select something that you learned about mangrove forests. Compose a 10-line poem about what you learned. Your lines do not need to rhyme, but they may rhyme. Share your poem with your classmates.

Natural Inquirer Connections

You may want to reference these *Natural Inquirer* resources for additional information and FACTivities:

- Hawai'i-Pacific Islands edition—"Mangrove Mania: How Elevation Change and Sea-Level Rise Affect Mangrove Forests"
- Freshwater edition—"Sediment-al Journey: Measuring Metal Concentrations in Soil Beside Urban Waterways"
- Carbon Series monograph—"Logjams and Beaverdams: How Different Landforms Affect the Amount of Carbon in an Ecosystem"
- Animals, Ecosystems, and Cultures of the Pacific Islands edition—"Welcome to McMangrove's! Determining the Importance of Mangrove Leaves in a Tree-Climbing Crab's Diet"
- Hawai'i-Pacific Islands edition—"Beam Me Down, Scotty! The Use of Airborne and Satellite Technology to Measure Carbon in Hawaiian Forests"
- *Natural IQ* edition—"Everything but the Carbon Sink: Carbon Storage in the Southern United States"

These resources, along with others, can be found at https://www.naturalinquirer.org/all-issues.html.

Web Resources

National Geographic: Sediment
https://www.nationalgeographic.org/encyclopedia/sediment/

National Oceanic and Atmospheric Administration: Is sea level rising?
https://oceanservice.noaa.gov/facts/sealevel.html

National Oceanic and Atmospheric Administration: What is a mangrove forest?
https://oceanservice.noaa.gov/facts/mangroves.html

National Environmental Education Foundation: Marshes, Estuaries, and Mangroves, Oh My!
https://www.neefusa.org/nature/land/marshes-estuaries-and-mangroves-oh-my

Project Learning Tree®

If you are a Project Learning Tree educator, you may use "Watch on Wetlands" or "Soil Stories" as an additional resource.