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MANGROVES

LIVING ON THE EDGE IN A CHANGING CLIMATE

Place-based resources for Pacific Island schools

DEDICATION

For students, teachers and communities living in tropical Pacific island environments.

TABLE OF CONTENTS

WHY LEARN ABOUT MANGROVES?

Mangroves guard our coasts. You may think of them as trees or shrubs that simply grow along some of your island's shores, seemingly not doing much. Actually, the mangroves are quite busy performing many important functions!

They work hard to survive in the flooded and salty environment in which they grow, and their work helps us in many ways. Mangroves stabilize our land and defend our shores against damage from the ocean. Mangroves protect our reefs and lagoons from harmful runoff and pollution. Mangroves act as nurseries for fish and other organisms. They provide a safe home for marine life and other wildlife.

When you learn about the mangroves from this book, you will look at them not as simple trees, but as one of the most precious resources we have on our islands. They provide for us and protect us. While they have **adapted** to thrive in their naturally changing environment (e.g., daily high and low tides, more or less fresh water depending on rain), they face additional changes in their environment as a result of human activities and climate change impacts. Let's learn about our island mangroves and how we can take better care of them in a world where the climate is changing.

WHAT ARE MANGROVES?

Mangroves are trees that grow in warm, shallow coastal areas that are regularly flooded by seawater from the ocean.

Mangroves are odd-looking trees. Some appear to be supported by long stilts growing out of the trunks, while other mangroves are surrounded with strange upward-pointing spikes coming out of the ground. Even more unusual, we never see them away from the coast. They grow only where there is plenty of water, much of it quite salty. During some periods, they are flooded almost entirely by seawater and seem to grow straight from the ocean. This is something that only mangroves can do. No other trees can grow with so much salty water.

Though we can see a lone mangrove tree here and there, mangroves are generally clustered together, forming large groups of trees. That is why we often refer to mangrove trees as "the mangroves."

The name "mangrove" can refer to individual plants, but also to the entire forest, habitat, or ecosystem in which they live.

ARE ALL MANGROVES THE SAME?

You have probably noticed that there are different kinds of mangrove trees. For example, their leaves and flowers can be different shapes and colors. Scientists use the same name for these different trees because they all have the very unusual ability to live in shallow, salty coastal waters. All organisms have adaptations that help them live and **reproduce** in their environments.

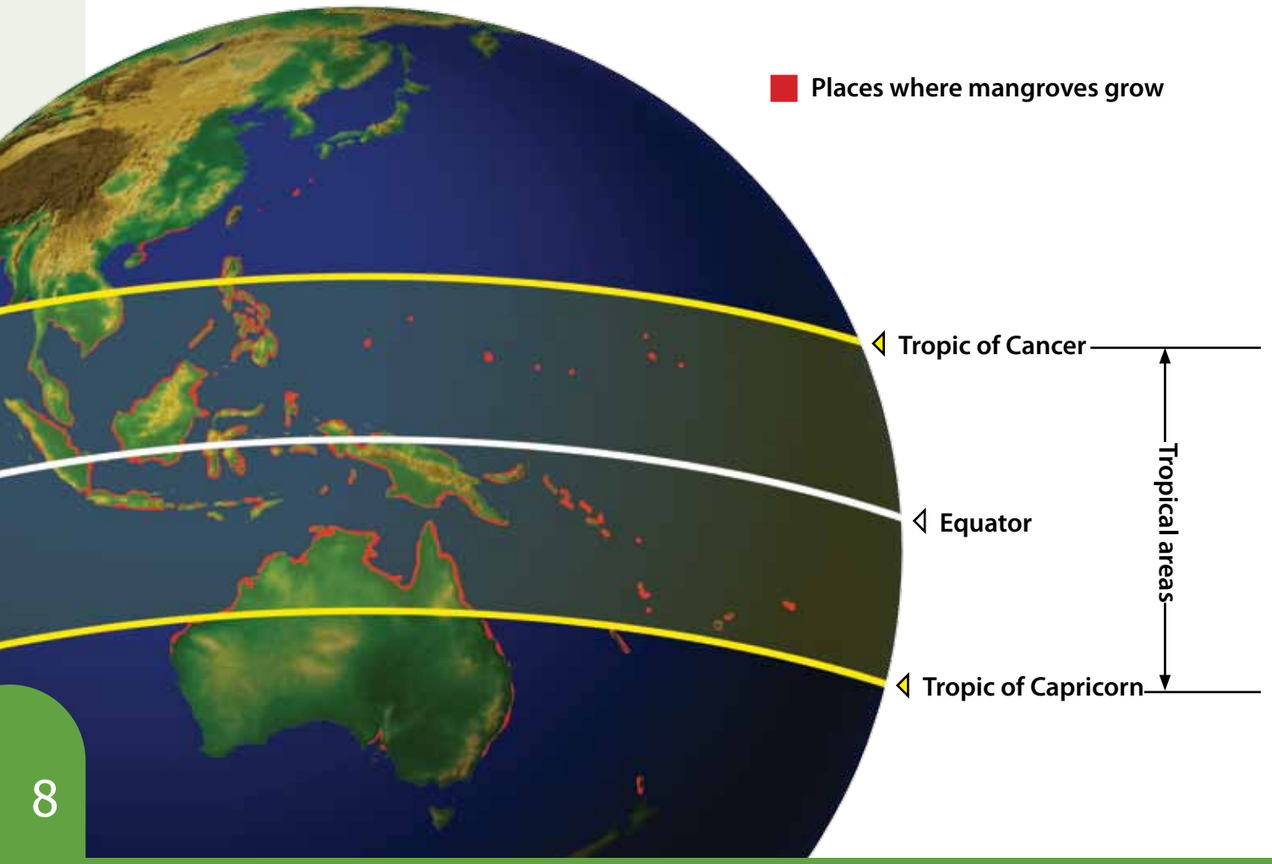
In the next pages, we will learn about the environments where mangroves grow and the adaptations that make it possible for them to grow where no other trees can live.

WHERE DO MANGROVES LIVE?

Mangroves are not found everywhere. They grow only in places near the Equator. More precisely, they grow in tropical regions, mainly between latitudes 25 °N (called the Tropic of Cancer) and 25 °S (called the Tropic of Capricorn). We find them along the coast, in relatively quiet places such as lagoons, bays, and estuaries.

Mangroves occur in the areas between the shore and the sea. These areas are flooded by the sea every day. Mangroves grow along coasts with seawater.

Coastal areas are tough places for plants to grow—too much salt kills plants. To add to the challenge, parts of the coast are covered by seawater during high tides, and are exposed to air during low tides.



Mangroves grow in places with the following conditions:

a SOFT GROUND

Mangrove trees require soft ground to grow. Mangrove roots that support the trees can only grow in soft material; they cannot penetrate hard rock. Mangroves grow best in muddy or sandy soils. Sometimes, you may notice a mangrove tree that seems to grow out of coral rock, but its roots are actually growing in narrow cracks filled with mud or sand.

b SHELTER FROM STRONG WAVES

Strong waves can wash away the mud and sand, destroying the soft ground that mangroves need to grow in. That is why mangroves grow best in coastal areas that are well sheltered from waves and have plenty of soft ground to take root in.

c SHALLOW INTERTIDAL SHORES

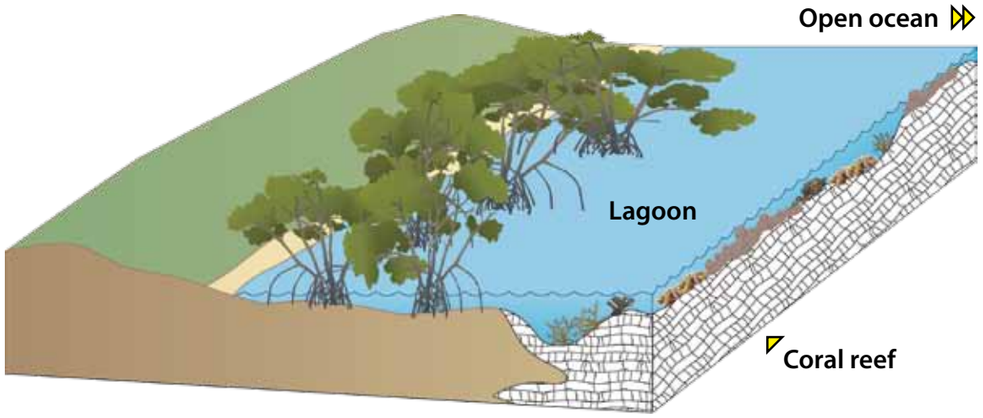
Mangroves grow best on the ground that is covered by seawater at high tide and uncovered at low tide. These shallow areas between the tides are called intertidal. Mangroves thrive in shallow intertidal areas, and cannot survive in water that is too deep. If the shore is flat, then the shallow intertidal area is wide and mangroves have lots of space to grow. If the shore is steep, then the shallow intertidal area is narrow and mangroves have little room to grow.

d WARM TEMPERATURES

As the illustration of the planet shows, mangroves grow mostly in tropical places. They need the temperatures to be warm all year. The further one gets away from the tropics, there are fewer types of mangroves. They grow in a few other warm places, but cannot be found where the winters are cold.

REEF-SHELTERED COASTS

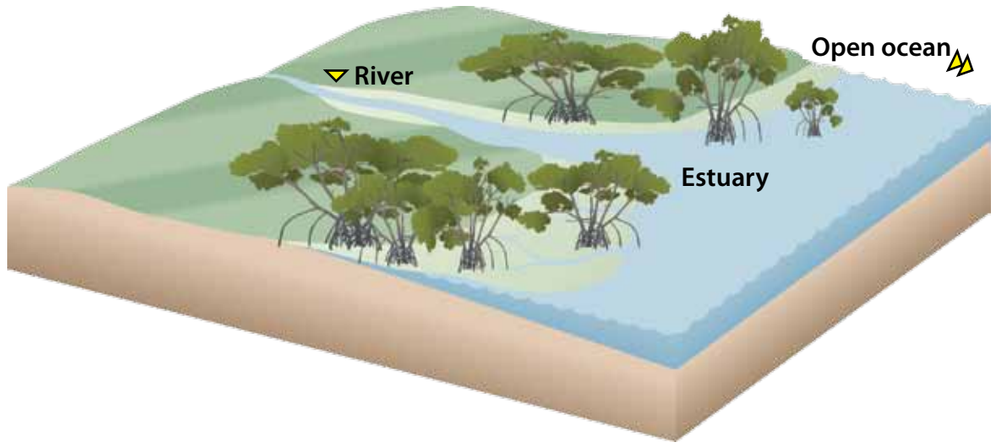
On Pacific Islands, coral reefs provide excellent shelters from waves. The reefs break the waves and prevent them from getting through to the shore. Mangroves thrive in the quiet waters sheltered by coral reefs.



Mangroves growing behind a coral reef.

BAYS AND ESTUARIES

Other places sheltered from waves include bays (places where the shoreline curves and partly encloses a body of water) and **estuaries** (places where rivers reach the ocean and their fresh water mixes with seawater). The mixing of waters and plenty of mud found in the estuaries makes them great places for mangroves to grow. That is why we see many mangroves in the lower parts of rivers.

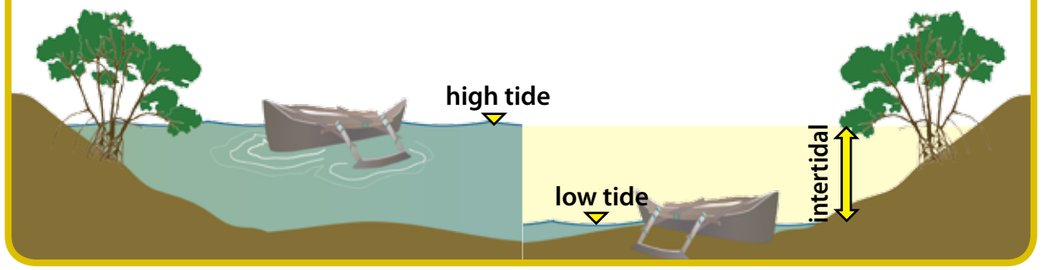


Mangroves growing along river banks in an estuary.

WHAT ARE TIDES?

You have noticed that the water level at the shore – where the land and the ocean meet – is not always the same. It is higher when the tide comes in. That time is called high tide. Water level at the shore is lower when the tide goes out. That time is called low tide.

High tide and low tide always follow each other. In the Pacific islands, two high tides and two low tides occur each day. Part of the shore that is dry during low tide but covered with water during high tide is called the intertidal zone.



MANGROVES AND TIDES

For a part of each day, the tide comes in and low-lying coastal areas are flooded by seawater. Mangroves appear to grow out of the ocean. The water is often **murky** because there is lots of mud mixed in.

Then, as the tide goes out, the water slowly drains away, and the ground from which mangroves grow may become dry. At low tide, we can see that the mangroves grow from wet, muddy, soft ground. We can see their strange roots, some branching out like many thin legs coming out of the trunk and reaching out to the mud around it, some roots looking like pencils pointing into the air instead of going down into the ground, and other roots taking more unusual shapes.

Before the day is over, another tide comes in and floods the mangroves, and then goes out, leaving them dry yet again. The never-ending cycle of the tides is the rhythm to which mangroves, and all the organisms that live among them, have adapted.

Photo of a mangrove swamp during high tide.

Photo of the same place as on the opposite page, six hours later.

HOW ARE MANGROVES ADAPTED TO THEIR HABITATS?

The places where mangroves grow are difficult to survive in because of the constant changes. Over the course of just one day, mangroves may be covered by seawater at high tide, exposed on dry land at low tide, or flooded by fresh water during periods of heavy rainfall. Other plants would quickly die in face of such challenges, but mangroves thrive. That is because they are specially adapted to live in such habitats. They are able to live, grow, and reproduce there because they have special structures and strategies to overcome the challenges they face.

Just like fish cannot live on trees, almost no plants can survive in places where mangroves live. That is because of several very challenging issues. These challenges include too much salt in the water, too little fresh water, lack of **oxygen** underground, and the muddy ground being too wet and soft.

THE MANGROVES' MANY CHALLENGES

THE SALT CHALLENGE
Too much salt in the water.

THE WATER CHALLENGE
Lots of water everywhere, but very little fresh water.

THE AIR CHALLENGE
Too little oxygen in the often flooded ground.

THE MUD CHALLENGE
Soft mud gives little support.

Mangroves are highly adapted plants that overcome the many challenges that exist in their habitats.

THE SALT CHALLENGE

Most organisms that live in water can survive only in specific types of water. For example, ocean fish require salty water and would quickly die if placed in a river. In turn, river fish require fresh water. They would suffer or die if the amount of salt in their water changes significantly. Not many organisms are able to live in water that is sometimes salty and sometimes fresh, and this is especially true of plants. The vast majority of plants are quickly killed by salty water. Yet, mangroves can live in places where the salinity (the amount of salt in the water) changes a great deal over short periods of time. They are able to do this because of unique adaptations that allow them to filter out salt when taking up water through roots, and also get rid of salts through specialized roots and leaves.

Mangrove roots can filter out salt. Roots and leaves can also get rid of it.

Mangrove leaves reduce water loss. They help conserve fresh water.

THE WATER CHALLENGE

Mangroves also deal with having too much water around. For example, if a seed from a regular tree falls directly into water, it would likely sink and die. Mangroves have found unique ways to **reproduce** under flooded conditions and even use water to spread seeds and seedlings from one place to another. Despite so much water all around, mangroves get little fresh water. They must reduce how much fresh water evaporates from their leaves.

Mangrove seeds and seedlings are adapted to reproduction in a flooded habitat.

THE AIR CHALLENGE

Plants need oxygen and usually get it through their roots from air in the soil. However, ground that is soaked in water does not have much air in it. Mangroves cannot find enough oxygen in the muddy ground where they grow. Instead, many mangroves have developed special roots that reach above the ground and get the needed oxygen directly from the air. These roots above ground take in oxygen and send it through the underground roots to the other parts of the tree.

Mangrove roots extend partly above the ground and can get oxygen directly from the air.

The mangroves extensive and entangled root systems firmly anchor trees in soft mud.

THE MUD CHALLENGE

Mangroves can be very large despite growing from mushy, muddy ground. Many trees could not stand upright in soft mud, but mangroves can because their roots are very extensive and **entangled**. They tightly hold the soft ground and keep the mangrove tree from falling over. Though their roots do not go very deep, they spread sideways in a dense mass over large distances. Many mangroves have more plant material below the surface than above, helping them remain anchored in the soft mud.

MANGROVE ROOTS

Almost any plant would quickly die if its roots were in the salty, soft, and soaked soil that mangroves grow in. A plant that is not especially adapted to such conditions would quickly fall victim to the salt, or would topple over in the very soft ground, or would be killed by the lack of oxygen in waterlogged ground.

Mangroves root systems are highly adapted and have parts above the ground.

Mangroves, in contrast, thrive in such places because they have special adaptations to deal with these challenges. Many of these special adaptations can be seen in the mangroves' unusual roots. Unlike most plants, large parts of mangroves' roots can be seen above the ground. These **aerial roots** (above-ground parts of the roots) have highly unusual shapes and functions, quite unlike the roots of other plants. We can readily recognize mangroves trees by their unusual roots.

There are two main ways that mangrove roots help mangrove trees grow in ground that is salty, soft, and soaked in water:

- ★ Mangrove roots are extremely good at keeping the salt out while allowing water to come in. They filter the water as it enters the tree. Some roots can even throw out salt from inside the tree.
- ★ Most mangroves have specialized and extensive root parts that grow above the ground. These roots help hold the plant firmly in the soft ground and can also get oxygen straight from the air.

Different mangroves have different root types. We distinguish them by the look of the above-ground parts. The main types are stilt roots (or prop roots), peg roots (or spike roots), knee roots, and buttress roots. Their underground roots filter the water they take in and prevent salt from getting to other parts of the plant, and their above-ground root parts take up oxygen. If the aerial roots are kept underwater or buried in mud for too long, they cannot get oxygen and the tree may die.

STILT (PROP) ROOTS

These roots grow down from branches and the trunk of a mangrove, reach the ground and anchor into it. They can form many loops to get a stronger grip. Criss-crossed roots make an almost impassable tangle.

PEG ROOTS

These roots look like upward-pointing spikes that stick out of the ground. They are covered by water during high tide, but can get oxygen from the air during low tide.

KNEE ROOTS

Some roots emerge above the ground surface, bend like a knee, and grow down into the ground again. They twist and connect with each other to cover the ground around a tree.

BUTTRESS ROOTS

Buttress roots are like straight or bent planks that grow out of the trunk and provide additional support to the tree. These buttresses have many small roots that grow into the soil.

MANGROVE LEAVES

Most plants cannot live in or very near salty water because salt makes the plant dry out. Even animals dry out if they eat a lot of salt. Think about how thirsty you feel after eating something very salty. Mangroves can live in salty places because they have adaptations to deal with excess salt and shortage of fresh water. Roots block entry or get rid of most of the salt from the water they take in. The salt that does get into the tree is dealt with by the highly adapted leaves:

- ★ Some species have leaves that store salt.
- ★ Some species have leaves that excrete (remove) salt.

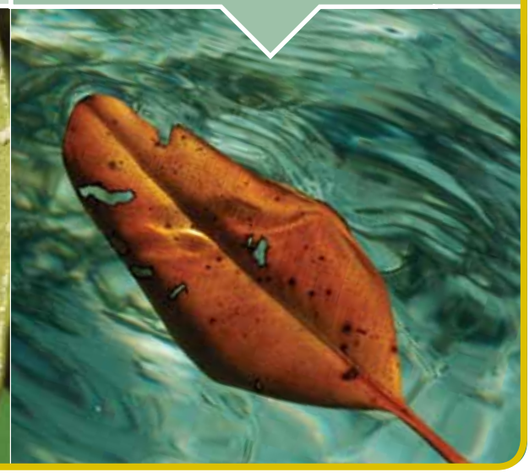
In addition, mangrove leaves help the plant conserve fresh water by stopping the water from quickly evaporating. These leaves often appear thick and juicy (full of water) and have a waxy surface that reduces the amount of evaporation.

EXCRETING SALT

You might notice tiny salt crystals on some leaves. Leaves push out salty water through tiny holes. When the water evaporates, salt is left behind on the leaf and washed away by rain.

STORING SALT

Mangroves can store excess salt in some leaves. These leaves turn orange and yellow and fall off the tree, taking the dangerous salt away with them.



MANGROVE FLOWERS, FRUITS, AND SEEDS

Like in nearly all trees, mangrove reproduction starts with flowers. Flowers contain male and/or female parts that combine to give rise to fruit. Within the fruit are seeds. If the conditions are right, seeds grow into new mangrove trees. Given the mangroves' challenging habitat, some special adaptations are required for reproduction to be successful. The fruits, seeds, and seedlings are all adapted to the intertidal habitat:

- ★ Mangrove fruit, seeds, and seedlings can float in water.
- ★ The seeds of some species start growing while still attached to the parent tree. These seedlings detach and float away.

FLOWERS

Mangrove flowers vary in size and color: from tiny to large, white, red, yellow. They are adapted to attract animals (insects, birds, bats) that pollinate them and help make flowers into fruits.

FRUITS

Mangrove fruits have a range of special adaptations. They float in water and have a fleshy or woody layer that protects the seeds inside. Some fruits burst apart when they dry up and release the seeds inside.

FLOATING SEEDS

Mangrove seeds come in a variety of shapes and sizes, and can float in water. Some sprout while still hidden inside the fruit, making them ready to quickly grow as soon as the fruit opens up.

FLOATING SEEDLINGS

Some species' seeds sprout while still on the parent tree! The seedlings eventually drop into the water below and float away. When they reach soil, roots grow quickly to keep the seedling from drifting away.

WHAT KINDS OF MANGROVES ARE THERE?

More than fifty different species of trees are called mangroves and they come from many different plant families. What are the most common types of mangroves in the Pacific islands?

There are many different species of mangroves.

In general, mangroves are trees adapted to life in the intertidal zone of **tropical** coasts. Though not necessarily related to each other, they live in the same or similar habitats and have developed similar adaptations. Because they live in similar ways, we think of them as a group. But when you look at mangroves, you notice that there is more than one kind. Some mangroves are huge trees that grow tens of meters tall, others are small trees and shrubs. There is a even a palm that lives in salty swamps and is sometimes considered a kind of mangrove. All these plants are different in overall shape, roots, leaves, flowers, and seeds, and may be specialized to grow in particular areas or under particular conditions. Let's examine on the following pages some species of mangroves that are typical to the Pacific islands.

Living with the mangroves are other plants that are not considered mangroves themselves. Smaller salt-tolerant plants – including mosses, ferns, vines, grasses, and orchids – grow on the ground and cover or hang from the branches and trunks of mangrove trees.

1 RED MANGROVE
Rhizophora species

Red mangroves' have stilt roots that hang from the branches or loop down from the trunk. These roots support the plant and take in oxygen. Leaves are oval and pointed, sometimes with fragile tips. The seeds germinate while still attached to the tree. Seedlings float away to become new trees.

- Carolinian: *schiiya*
- Chamorro: *mangle hembra*
- Chuukese: *chia*
- Kosraean: *suhkasrihk*
- Marshallese: *eoeak*
- Palauan: *tebechel* / *bngaol*
- Pohnpeian: *akelel* / *akapah*
- Woleaian: *shiyaa* / *maliili*
- Yapese: *rawëy* / *maliil*

2 WHITE MANGROVE
Sonneratia alba

White mangrove is a tall tree with many pencil-shaped peg roots that take up oxygen from the air. The leaves are rounded with leathery texture. Its dark red flowers open just for one night. The seeds are round and attached to a green, star-shaped base.

- Chuukese: *saaras* / *taaras*
- Kosraean: *fulohfohl*
- Marshallese: *būḷabōḷ* / *kōnpat*
- Palauan: *urur*
- Pohnpeian: *koatoa*
- Yapese: *afruur*

3 BLACK MANGROVE
Lumnitzera littorea

This tree is surrounded with tangles of knee roots above the ground. Its leaves are fleshy, light green in color and spoon-shaped. Each leaf has a small indentation at the tip. Many small white flowers grow in groups and produce small, green-colored seeds.

- Chamorro: ***nana***
- Chuukese: ***weey***
- Kosraean: ***oi***
- Marshallese: ***kimeme***
- Palauan: ***mekekad***
- Pohnpeian: ***weingal***
- Woleaian: ***wei***
- Yapese: ***yiiy***

4 ORANGE MANGROVE
Bruguiera gymnorrhiza

Orange (or Oriental) mangrove has buttress roots and knee roots. Its leaves are large and occur in clumps at the ends of branches. This tree is easy to identify by the beautiful red flowers that stand out in the green foliage. Attached to the flowers are large, green, crayon-shaped seeds.

- Carolinian: ***yoong***
- Chamorro: ***mangle machu***
- Chuukese: ***woong***
- Kosraean: ***sroal***
- Marshallese: ***joñ***
- Palauan: ***denges***
- Pohnpeian: ***sohmw***
- Woleaian: ***soongo***
- Yapese: ***roek***

5 CANNONBALL MANGROVE
Xylocarpus granatum

This mangrove tree has large buttress-type roots that look like planks spreading out from the trunk. It lacks knee or peg roots. The tree's most unusual feature is its large ball-like fruit. Each fruit contains several woody seeds that fit perfectly together, like pieces of a ball-shaped puzzle.

- Chamorro: ***lalanyok***
- Chuukese: ***pwunopwun***
- Kosraean: ***tuhi***
- Marshallese: ***lokobar***
- Palauan: ***medulokebong***
- Pohnpeian: ***pwulok***
- Yapese: ***yamguur***

6 MANGROVE PALM
Nypa fruticans

Quite unlike other mangroves, this tree is a palm. It is also quite unlike most palms because its trunk is completely underground – we see only the leaves and stalks with flowers and fruits. The fruit is truly unique: a large ball with spiky points, each of which is a seed that separates and floats away.

- Chamorro: ***nipa***
- Chuukese: ***kiyé***
- Kosraean: ***fahsuc***
- Palauan: ***toechel***
- Pohnpeian: ***parem***
- Woleaian: ***woloperame***
- Yapese: ***aying*** / ***ayung***

WHAT IS A MANGROVE SWAMP?

Mangrove trees are very rarely seen on their own. They usually grow clustered together. Large groups of mangrove trees and other plants that live with them are called mangrove forests, mangrove swamps, or, simply, mangroves.

A single mangrove produces hundreds of seeds each year. Not all of those seeds survive to become trees, but many do if the conditions are right. A single mangrove growing in a suitable place for many years will become surrounded by smaller trees, gradually creating a mangrove forest. Over time, the forest can become very large and cover wide stretches of coastline.

Because mangroves live in watery areas, their forests are frequently or always flooded. Such forests are called swamps. Therefore, the best term for a forest of mangrove trees is mangrove swamp.

Not all mangrove swamps are the same. Species that live there, height of trees, and other things change with location and conditions. A mangrove swamp can have one or two mangrove species, or contain many more. Their height can be from a few meters to tall trees over 10 meters high. The swamp can be relatively open, or so dense that the intertwining branches and roots of tightly packed trees make it almost impossible to walk through it.

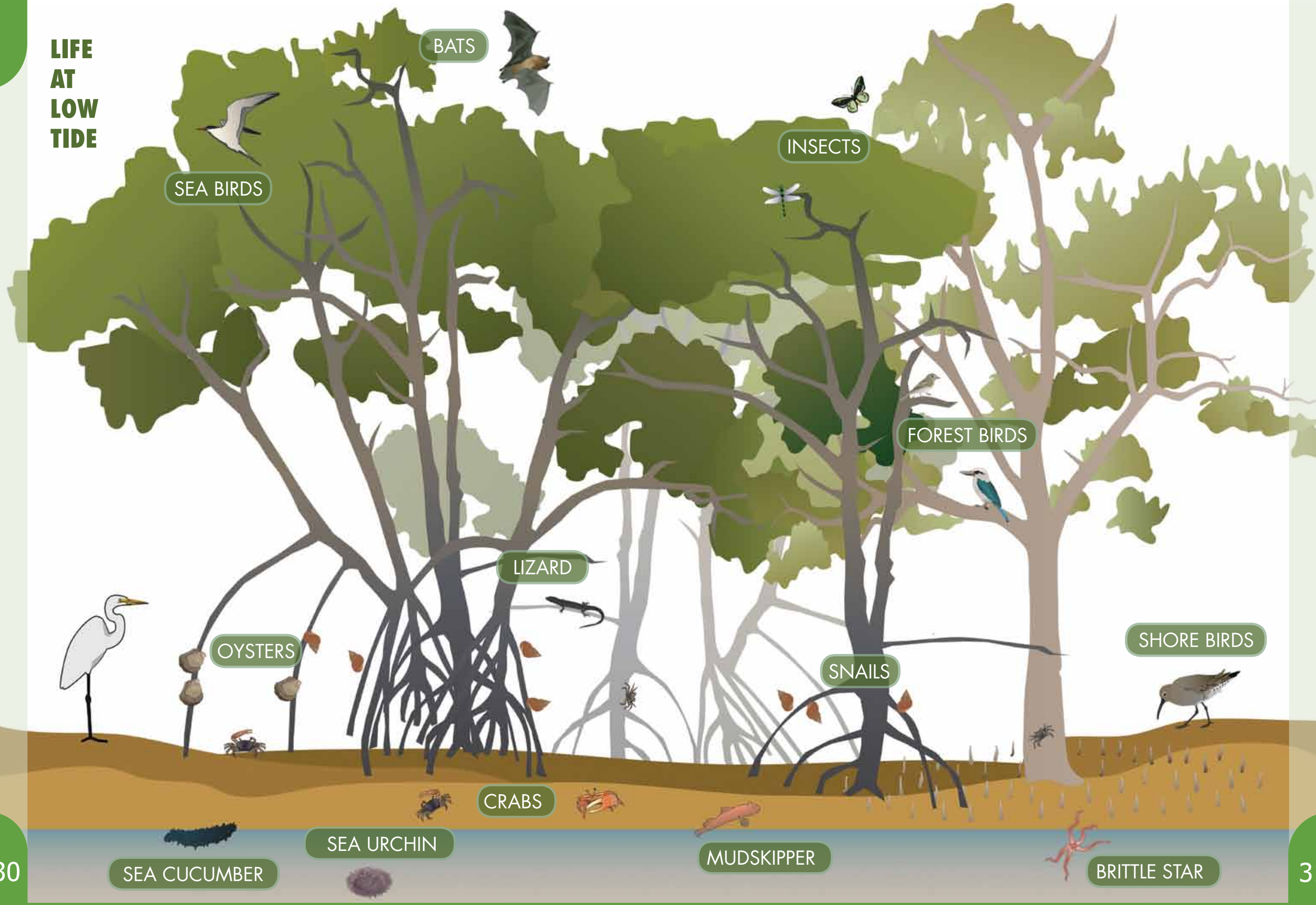
WHO LIVES IN A MANGROVE SWAMP?

In addition to the mangroves themselves, numerous other living things make their home in a mangrove swamp. They live, feed, grow, interact, and reproduce in mangrove habitat.

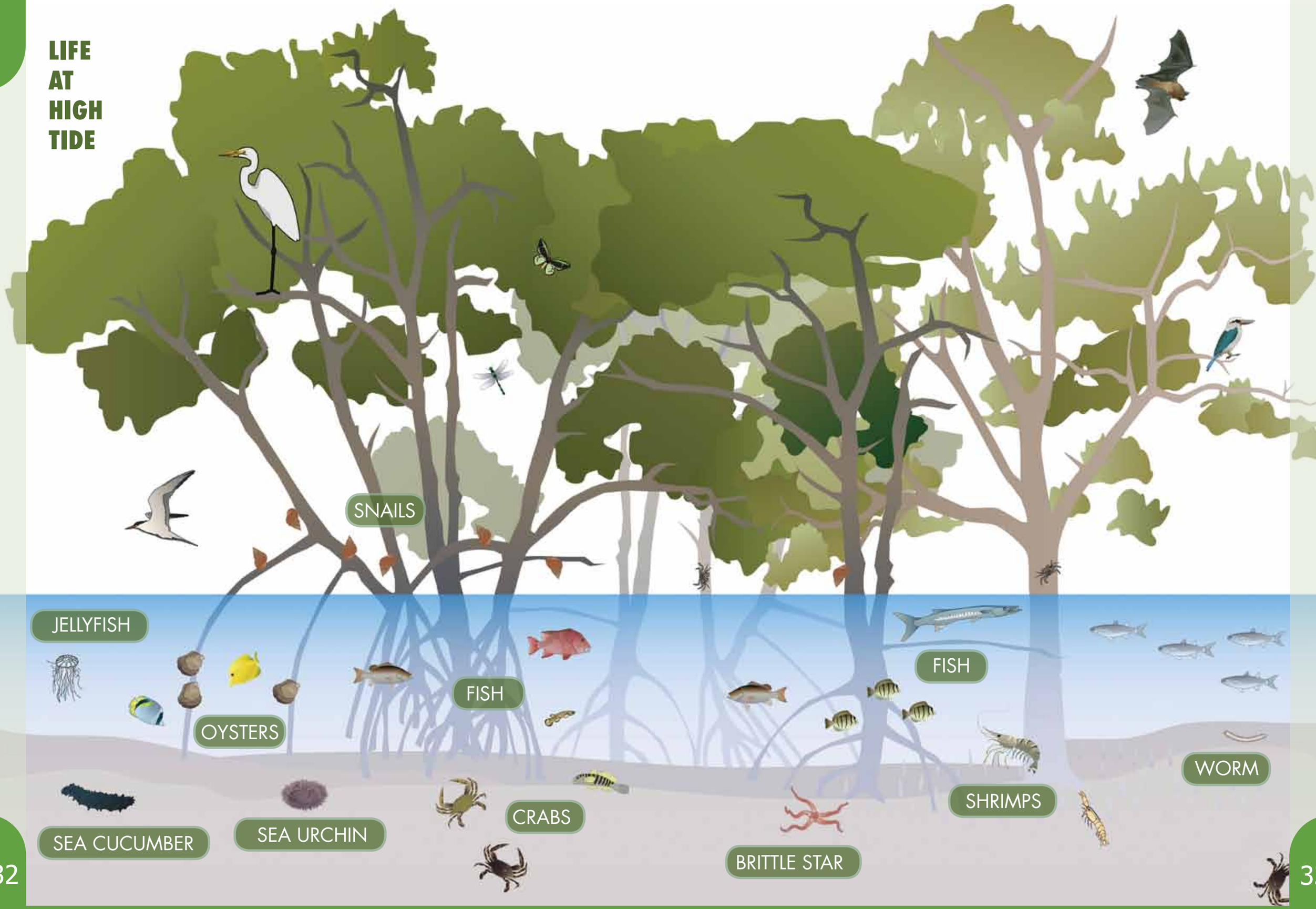
Many living things, including smaller plants (such as mosses, ferns, grasses), **microorganisms** (tiny living things that can be seen only with a microscope), **invertebrates** (animals lacking a backbone), and **vertebrates** (animals with a backbone) are able to find food, shelter, and safe place to reproduce among the mangroves' lush branches and entangled roots.

Mangrove swamps are full of life. Mosses and ferns cover some of the tree trunks and hang from the branches. Insects, lizards, birds, and bats live in holes in the trees and in the forest canopy. Tree-climbing crabs and snails go up and down the trees as the tides rise and fall. Algae, sponges, barnacles, mussels, oysters, and other organisms live attached to wet tree trunks and roots. Scrambling across the roots and the muddy bottom are worms, snails, shrimp, crabs, sea cucumbers, sea urchins, and fish. Some of them, such as some snails and mudskipper fish, can live outside water during low tides. Others, such as worms and fiddler crabs, hide during low tide by digging into the mud. In the process, they let air into the mud which improves the health of the mangroves. Swimming in the water during high tide are many fish, including some that only visit to hunt or reproduce. All of these organisms depend on the mangroves for survival.

LIFE AT LOW TIDE



LIFE AT HIGH TIDE

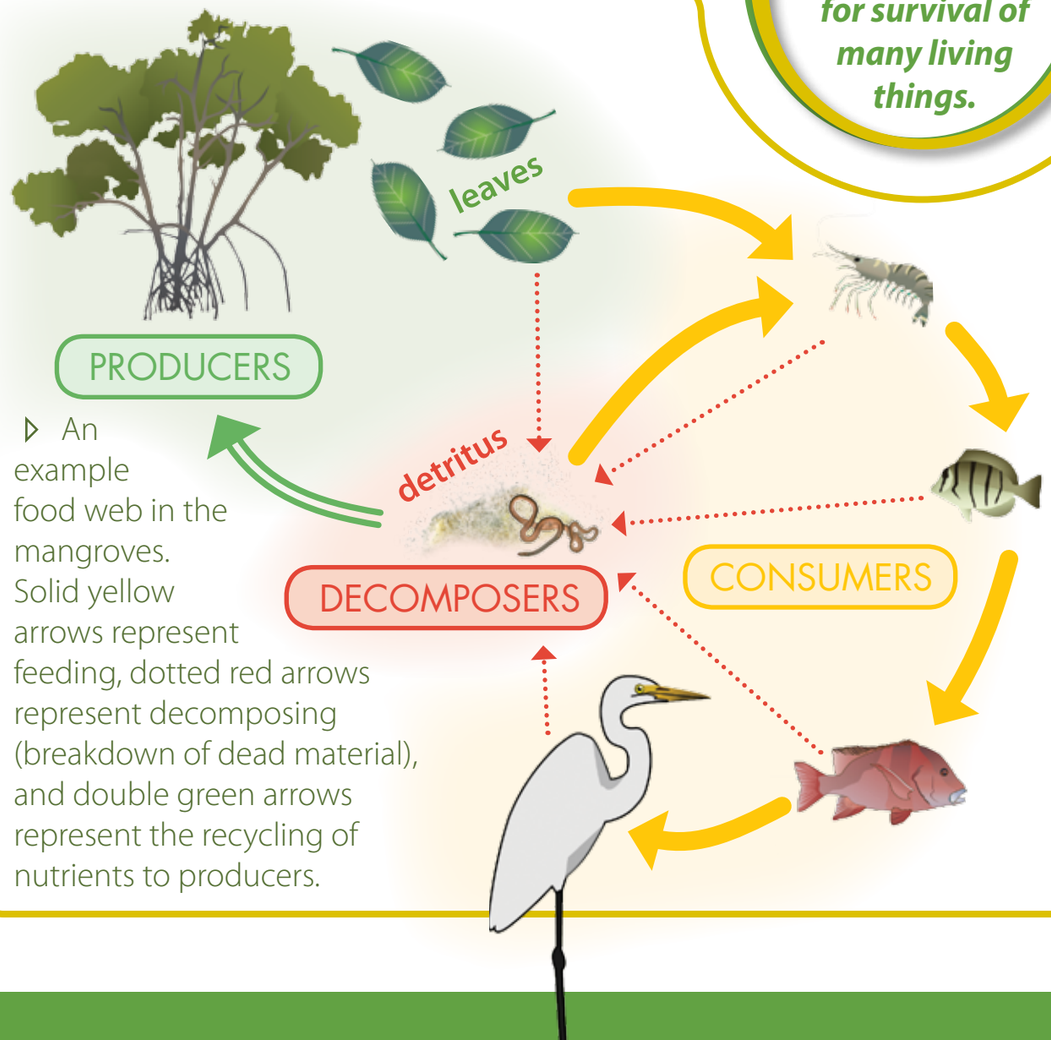


MANGROVES ARE NURSERIES

Mangroves are **nurseries** for many animals. Birds make their nests and raise young among the branches. Huge numbers of marine organisms spend their youth hiding in the murky water among the entangled roots, where predators cannot easily find and catch them.

Many fish that live on the reefs and in deeper water reproduce in the mangroves. Their young live in the mangroves until they grow big enough to move away to other habitats. Without mangroves, reef fish and many other marine life would not have a safe place to grow up and later come back to reproduce.

Mangroves are complex ecosystems vital for survival of many living things.



▷ An example food web in the mangroves. Solid yellow arrows represent feeding, dotted red arrows represent decomposing (breakdown of dead material), and double green arrows represent the recycling of nutrients to producers.

MANGROVE ECOSYSTEM

Like all plants, mangroves **produce** or make their own food from sunlight, CO_2 and water (**photosynthesis**). In turn, they become food for living things that cannot make their own food and must find things to eat.

When leaves drop from a tree into water, **bacteria**, fungi and some small animals such as crabs feed on them. As they **consume** (eat) the leaves, these organisms turn the leaves into tiny bits called **detritus**. This detritus becomes food for other animals: sponges, corals, worms, snails, clams, shrimp, crabs, sea cucumbers, and sea urchins. Some of them – sponges, oysters, and barnacles – do not move about. They resist the fast flow of tides by attaching to mangrove roots where they filter the passing water and trap tiny pieces of detritus to eat. Others, such as shrimp and sea cucumbers, scramble over the bottom and browse through the mud, picking out detritus for food. Fish eat these various animals. In turn, the fish become food for other fish, which are themselves eaten by the even larger fish or birds, continuing the food web. We humans are a part of this food web. We eat crabs, fish, and other animals that live or reproduce in the mangroves.

When any animal in this food web dies, its body sinks to the bottom. There, microorganisms and small animals feed on it and **decompose** (break it down) into detritus. If you ever walked in a mangrove swamp at low tide, you may have noticed that the wet ground can be smelly. If your feet sink into the soft mud, more of the smell comes out. This smell is caused by microorganisms that break down the detritus and cause it to rot. The detritus is a part of the soil and helps nourish the trees by providing them with important nutrients. Trees take up nutrients dissolved in the water and use these nutrients to support their own growth and development. All of these organisms – plants and animals – live, feed, grow, interact, and reproduce in the complex **ecosystem** supported by the mangroves.

WHAT OTHER HABITATS ARE NEAR MANGROVE SWAMPS?

Mangrove swamps have important neighbors. Typically, going from the mangroves toward the ocean, one encounters seagrass beds and coral reefs. Going toward the land one finds wetlands and woodlands.

The mangrove swamps and these neighboring habitats are all interconnected and depend on each other in many ways. What happens in one habitat affects the other habitats as well.

Mangrove swamps are in the middle of a chain of interconnected ecosystems from the ocean reef to the mountain forest.

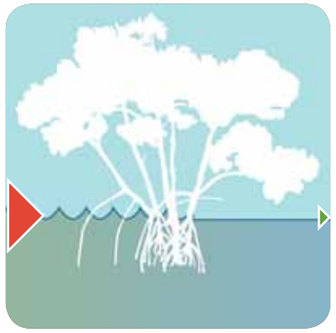
After visiting a mangrove swamp, if you move toward the ocean, you will see that the bottom is covered by seagrass – a plant related to the grass we see on dry land, but adapted to life in shallow coastal areas. They form underwater bunches we call seagrass beds. Like mangroves, seagrass beds are important nursery habitat for small fish and other marine life. Moving to deeper water, we find that the bottom changes from muddy to sandy and is covered by corals. Many corals growing together form a coral reef. These reefs are home to many fish and other organisms, some of which grew up in the safety of mangrove swamps and seagrass beds before moving to live on the reef as adults.

Going in the opposite direction, from the mangrove swamp inland, the land gets higher and drier. You may pass through a wet area known as wetland. It is covered with plants adapted to life on soggy ground, but with much more fresh water than seawater. Further inland are woodland areas, covered with wild and planted trees, and also various other habitats, including villages and towns where people live.

WHY ARE MANGROVE SWAMPS IMPORTANT?

Mangrove swamps provide many services and resources. Without mangroves, life would be much harder for island wildlife and human communities.

Mangroves are barriers that strengthen coasts and reduce erosion. They protect natural and man-made areas on islands, including villages and farmlands. Mangroves improve water quality by removing **sediments** and pollutants from the water. Mangroves protect other ecosystems such as coral reefs, and give safe homes and nursery areas for fish and other wildlife. Mangrove swamps also provide us with food and resources, and support our island's economy.

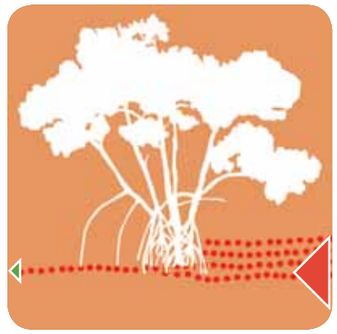


1 PROTECT COASTS

Mangrove swamps act as wave breakers. They reduce the forces of waves, winds, and water currents. In that way, mangroves protect the natural environment and human communities from strong winds, storm surges, high waves, and even tsunamis.

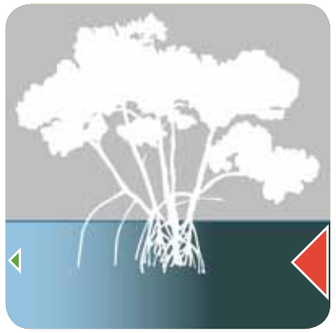
2 REDUCE EROSION

Mangrove root systems hold tightly to the soil. These roots prevent the muddy soil from being easily eroded (washed away) by waves and tides.



3 TRAP SEDIMENT

Mangrove roots catch and hold sediments (loose mud and sand). The ground around mangroves thus builds up from materials washed from the land by rains and rivers. This trapping reduces the amount of sediments that enter the ocean, thus protecting corals and other marine life.



4 FILTER WATER

In addition to sediments, rivers carry nutrients, chemicals, and other pollutants from the land. Mangroves trap and recycle or store these materials. They filter water and improve its quality.

5 PROVIDE HABITAT

*Mangroves are highly valued for their unique **biodiversity**. Many marine invertebrates, insects, fish, reptiles, birds, and mammals – including rare and endangered species – live, feed, or reproduce there.*

6 SERVE AS NURSERIES

Murky water and entangled roots give young fish places to hide from fish and birds that try to eat them. That makes mangroves excellent nursery areas for fish, crabs, and other marine life.

7 PROVIDE FOOD

Mangroves are a great source of food (and income) where people can get fish, crabs and clams. Even a lot of fish and other marine animals that we catch on the reef and in other places spend a part of their life cycle in the mangroves.

8 PROVIDE MATERIALS

We use wood of mangrove trees in cooking, building shelters, and making tools, fishing gear, and crafts. Certain local medicines are obtained from the mangroves. On some Pacific islands, leaves of the mangrove palm are the primary material for making thatch roofs.

9 TOURISM & RECREATION

Parks, beaches, and picnic areas with mangroves offer great recreational and educational opportunities. Children play and families spend free time there. Students can learn a lot by visiting. Tourists come to admire this fascinating habitat that they may not have at home.

Mangroves and coral reefs are close neighbors. They have a truly special relationship and take care of each other. Reefs help protect the mangroves from waves and storms. Mangroves help protect the reefs from sediments and pollution from the land.

THE REAL COAST GUARD

Have you seen people build seawalls against waves and coastal erosion? Within a relatively short time of being pounded by waves, those man-made barriers often crumble and fall. Reefs and mangroves are like living walls that protect the coast against the destructive forces of the ocean.

Ocean waves first break against the reefs. The waves then reach the mangroves with less force. The mangroves further weaken the impact of the waves. Their entangled, net-like roots extend through the soil, mud, and sand and keep it all firmly in place.

Mangrove roots help keep the land from being washed into the ocean. They thus stabilize the land and resist erosion. Even if a very strong storm destroys some mangroves, seedlings will sprout and grow into trees that replace the ones that were lost.

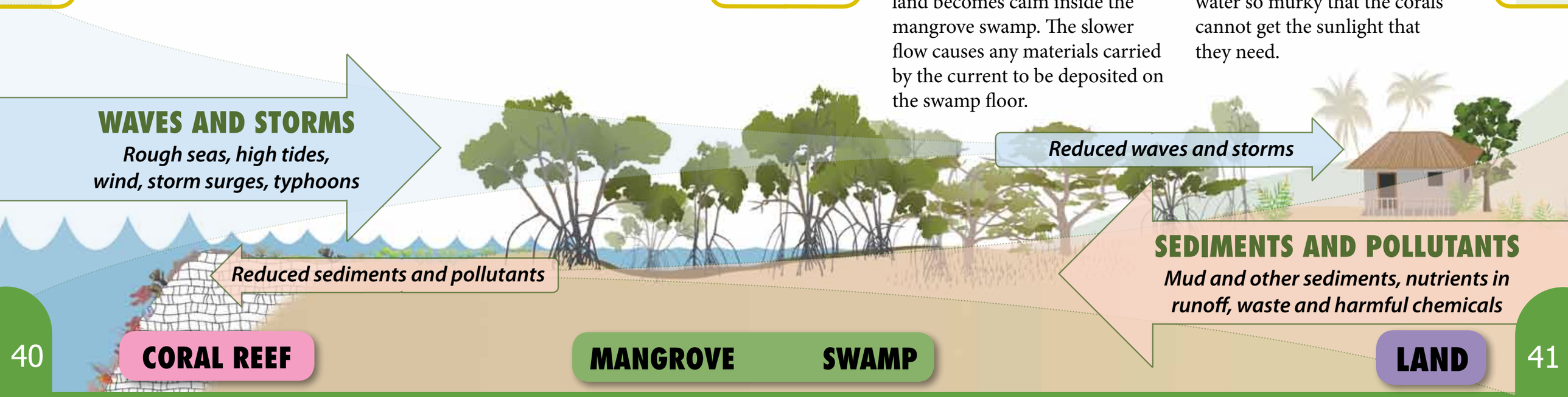
WATCHING EACH OTHER'S BACK

Coral reefs perform an important service to the mangroves by weakening waves coming from the ocean. When these waves reach the mangroves, they are already reduced in force and are made even smaller as they travel through the swamps full of mangroves' strong and entangled roots. The water inside the mangrove swamp and at the coast can be calm even when the reef and outermost mangroves are experiencing large waves.

The mangroves definitely return the favor to the coral reefs. Because the mangroves' roots slow down water current, the flow of any streams and rivers that come from the land becomes calm inside the mangrove swamp. The slower flow causes any materials carried by the current to be deposited on the swamp floor.

In addition to mud and sand, the deposits include harmful substances that were released on land as pollution and were washed down to the coast by rain. In addition, small organisms that live on the mangrove roots feed by filtering water and removing food particles from it. When that water goes from mangrove swamps out to sea, it is a lot clearer and cleaner than it started.

The mangroves filter the dirty runoff water from the land and thus help coral reefs to grow. If pollutants and sediments are not removed from water, they can cause great harm to corals and other marine life. Sediments can kill corals by settling on and covering them or by making the water so murky that the corals cannot get the sunlight that they need.



WHAT HUMAN ACTIVITIES HARM MANGROVES?

As we have learned, mangroves are a very important part of our island environment. Plants and animals, including us humans, depend on them for survival, health, safety, and food. Sadly, many human activities harm mangrove swamps.

There are four main ways that human activities directly harm mangrove swamps:

- ★ destroying habitat
- ★ creating sediment
- ★ overharvesting
- ★ polluting

People cause the largest harm to mangrove swamps when they cut down the trees and fill in the swamp to create space for agriculture, aquaculture (fish farming), or building of marinas. While these development activities can help people have food, income and jobs, the biggest cost is that another mangrove swamp has disappeared.

Some human activities create a lot of sediment. These activities include building roads, cutting upland forests, and dredging rivers and bays. Too much sediment buries the trees' aerial roots, and cuts off their oxygen supply.

Even mangrove swamps that are protected from development can be harmed if families take too much wood or catch too many crabs and fish. Many elders and traditional practices teach how communities can get the wood and food that they need without harming the natural ecosystems.

Mangroves can filter some harmful things from water. However, too much pollution harms the mangroves and weakens the ecosystem. This pollution includes untreated human and animal waste, garbage, pesticides and fertilizers used in growing food, and leaking of oil and other chemicals.

DESTROYING HABITAT

Clearing and filling of mangroves not only destroys them directly, but also changes the flow of water in a wider area. Too much or too little fresh water can affect the growth and health of mangrove trees in nearby areas.

CREATING SEDIMENT

Cutting upland trees and building roads can cause soil to be easily washed by rains toward and into the ocean. Dredging stirs up a lot of sediment.

OVERHARVESTING

If people harvest too many trees for wood or too many animals for food, these activities weaken the entire mangrove ecosystem.

POLLUTING

Many harmful things such as plastic, garbage, broken cars, chemicals, sewage and animal waste get thrown or washed into mangrove swamps. Spilled oil can stick to mangrove roots and reduce the supply of fresh water and oxygen to mangrove trees.

HOW DOES CLIMATE CHANGE HARM MANGROVES?

We have learned that mangrove trees have many adaptations that help them grow well in their coastal environments. Mangroves live very well with the kinds and amounts of salt, temperature, storms, and fresh water that have existed for the past thousands of years. But how well will they continue to grow if these conditions change in new ways?

Earth's climate is changing because humans are changing our planet's atmosphere. We burn lots of oil, coal and gas. This burning produces gases (especially carbon dioxide) that trap heat in the atmosphere. This trapping of heat in the atmosphere is causing Earth's climate to get warmer and to change in other ways. You can learn more about climate change on pages 52-57.

A warmer climate will cause changes to the rain patterns in the Pacific islands. Some places may have stronger and more frequent storms. There may be more rain than normal. Or some places may have more and longer periods of drought.

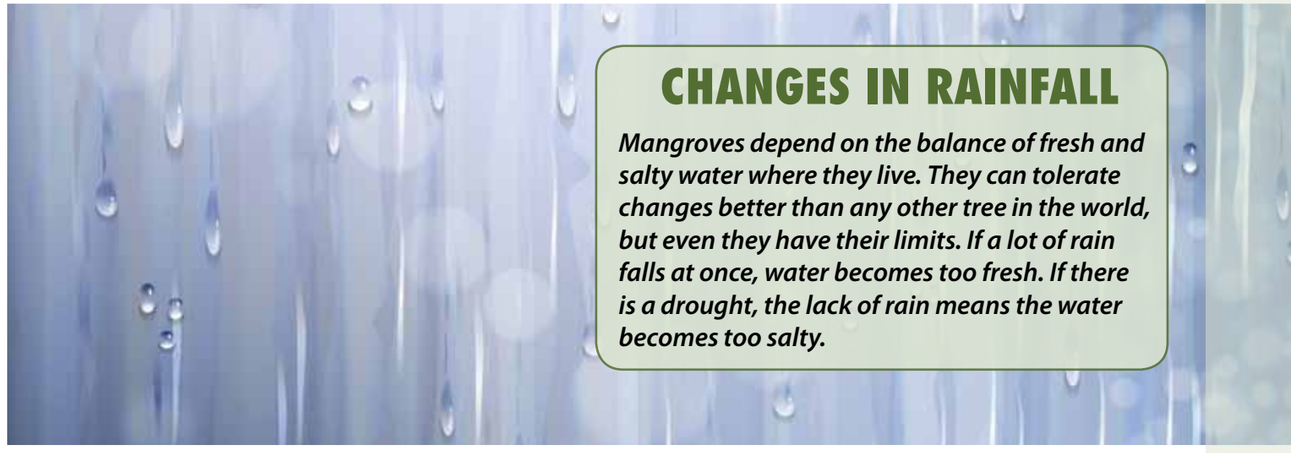
In distant very cold parts of the planet, warming of the climate is causing ice in polar ice caps and in mountain glaciers to melt. Water from the melting ice flows from the land to the ocean, and causes the sea level to rise. Higher sea level will flood some coastal lands, harm coastal ecosystems by adding more salt onto the land and into groundwater, erode shorelines, and wash away soil.

Four of the main ways that climate change can harm mangrove swamps are:

- ★ rising sea level
- ★ changes in rainfall
- ★ destructive storms
- ★ ecosystem damage

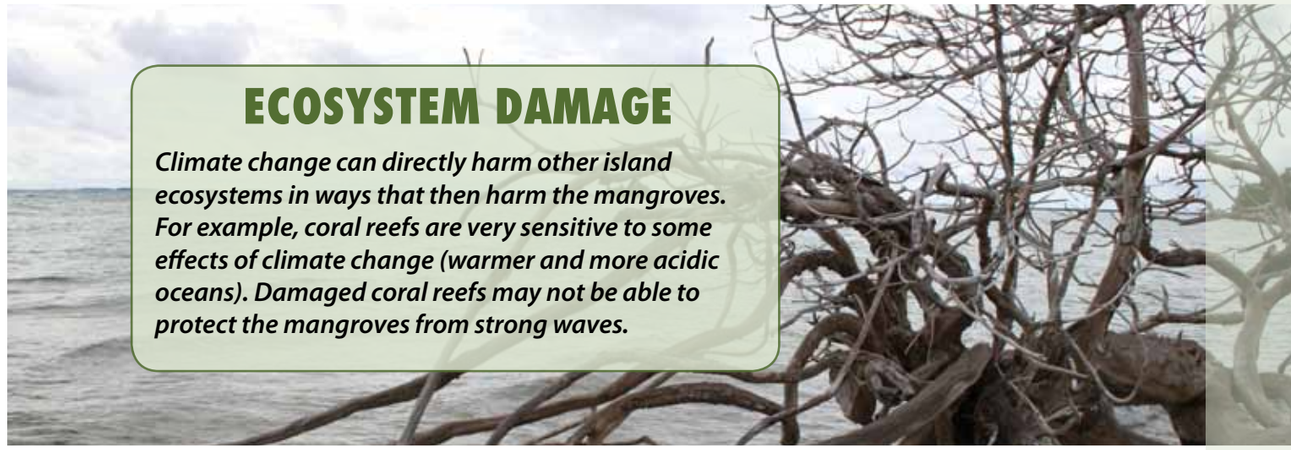
RISING SEA LEVEL

The rise in sea level is extremely dangerous because it can flood and destroy the places where mangroves grow. In addition to destroying habitat, sea level rise can cause more erosion of the coast and can make water in the ground way too salty for even mangroves to survive.



CHANGES IN RAINFALL

Mangroves depend on the balance of fresh and salty water where they live. They can tolerate changes better than any other tree in the world, but even they have their limits. If a lot of rain falls at once, water becomes too fresh. If there is a drought, the lack of rain means the water becomes too salty.



ECOSYSTEM DAMAGE

Climate change can directly harm other island ecosystems in ways that then harm the mangroves. For example, coral reefs are very sensitive to some effects of climate change (warmer and more acidic oceans). Damaged coral reefs may not be able to protect the mangroves from strong waves.

DESTRUCTIVE STORMS

Strong storms, particularly typhoons, may become stronger. Mangroves can suffer greatly if storms become much stronger than they are now.

HOW WOULD DAMAGE TO MANGROVES AFFECT YOUR ISLAND?

Damage to mangroves or their loss can have terrible effects on a particular area or even the island as a whole.

As we learned, mangrove swamps provide habitat, resources, and services to living things, people included, and the environment as a whole. Damage to mangroves can cause many dangerous effects.

MORE EROSION AND LAND LOSS

Mangroves protect the coast and resist erosion. Their roots hold the soil and keep it from being washed away. Mangroves trap sediments and build new land. They slow down waves and flooding water.

Soil and sand are washed away, trees fall down, and the shoreline moves inland. Waves, floods and storms cause more damage. Coastal areas get smaller, saltier and many plants die.

DIRTIER COASTAL WATERS

Mangroves filter runoff from the land. They reduce the amount of sediment and pollution, and make the water cleaner and clearer. This filtering helps keep marine ecosystems and organisms healthy.

Without mangroves, muddy water enters the ocean. Many organisms suffer from more sediments and pollution. Sediments pile on top of seagrass, coral, and other plants and animals on the seafloor. Coral reefs and seagrass beds are damaged.

Without mangroves to protect us, damage to the coast by waves and storms would greatly increase. The ocean would come further inland, and some lands would be lost. Groundwater would get saltier. Many plants would die. More sediments and pollutants would reach the ocean, reducing water quality and greatly harming coral reefs and other coastal ecosystems. Many organisms would lose home or nursery areas. Fewer fish and other food from the ocean would be available to us. There would be less firewood, construction materials, and local medicine. Our way of life would suffer if there is more damage to mangroves from climate change in addition to continuing damage from human activities that destroy habitat, increase sediment, overharvest, and pollute.

LESS BIODIVERSITY

Mangroves provide essential habitat for many plants and animals that live there or visit there to feed or reproduce. Many reef fish and other marine organisms are born and spend their youth hidden from predators in the safety of the mangroves.

When mangrove swamps are destroyed or damaged, many plants and animals lose their homes or nurseries, and disappear. There are fewer different kinds and amounts of organisms.

LESS FOOD AND OTHER RESOURCES

Mangroves are the home or nursery for many crabs and fish that people catch and depend on for food. The mangrove swamp also provides a source of wood for fires and construction, plants for medicine and other resources.

People will have less food, wood and other resources that they currently depend upon.

WHAT CLIMATE ADAPTATIONS CAN HELP PROTECT THE MANGROVES?

If a plant or animal is not getting what it needs, such as enough water or sunlight, then that plant or animal becomes weak. If another harmful thing happens to it, such as germs attacking it, the weak plant or animal will probably become sick and take a long time to get better.

In contrast, a plant or animal is stronger if it is getting the important things that it needs and if it has few harmful things happening to it. The stronger organism is less likely to suffer damages when a dangerous thing happens, such as germs attacking it, and if it is damaged, it is more likely to get better sooner. We say that a healthy, strong organism is **resilient**.

Similarly, ecosystems such as mangrove swamps can be weaker or stronger depending on what is happening to them. Human activities such as polluting, dredging, cutting down too many trees, catching too many fish and replacing natural areas with buildings can all harm mangrove swamps. A mangrove swamp that has been harmed by these activities is likely to suffer more damage from a climate change impact such as rising sea levels.

By minimizing human impacts on mangroves, we can improve their resilience to climate change

In contrast, a mangrove swamp that has been protected from these kinds of damaging human activities will generally be more resilient with respect to the impacts of climate change. For example, when there is flooding due to sea level rise these protected mangrove swamps are likely to suffer less damage and recover faster than mangrove swamps that have not been protected from development, pollution, and overharvesting.

HOW CAN A COMMUNITY START?

We use the term **climate adaptation** to describe the things that people, communities and governments can do to help protect local ecosystems from harmful climate impacts. The best ecosystem climate adaptations are activities that help the ecosystems return to and keep their natural conditions. These activities include preventing and removing pollution, and carefully managing human interactions with the ecosystem such as fishing, cutting trees, and development.

If human activities are damaging mangrove swamps, people need to decide as a community what to do about that. We know that healthier ecosystems are more resilient with respect to climate change. Healthier mangroves would suffer less damage from climate change, and after suffering such damage, they would be quicker to recover.

Communities can identify the most important mangrove swamps on their island and work to protect them from any harm from people. These protected areas could serve as fish and crab nurseries for the entire island and could constantly provide new mangrove seedlings to repair damage to mangrove areas elsewhere. Having at least several broad areas of healthy and well-protected mangroves can help make an entire island and its communities much better prepared for changes that the future will bring.

BIG IDEAS

KEY BENEFITS OF MANGROVES

Mangroves provide habitat, resources, and important services.

Habitat:
- ★ home to many plants and animals
- ★ important breeding areas for fish and crabs
- ★ nurseries for young fish and other sea animals

Resources:
- ★ fish and crabs for food
- ★ plant materials for building and thatching
- ★ source of plants used in local medicine
- ★ firewood for cooking

Services:
- ★ protect the land against floods and storms
- ★ resist erosion and make coast more stable
- ★ improve water quality by trapping sediments
- ★ provide space for recreation

MAIN THREATS TO MANGROVES

Human activities can directly harm mangroves.
Human-caused climate change can also harm mangroves.

- ★ destroying habitat
- ★ creating sediment
- ★ overharvesting
- ★ polluting
- ★ climate change
  - ★ rising sea level
  - ★ changes in rainfall
  - ★ destructive storms
  - ★ ecosystem damage

STRATEGIES TO REDUCE THREATS TO MANGROVES

The best climate adaptations for ecosystems are activities that help the ecosystem to return to and keep its natural conditions. These activities include preventing and removing pollution, and carefully managing human interactions with the ecosystem such as development, fishing, and cutting trees.

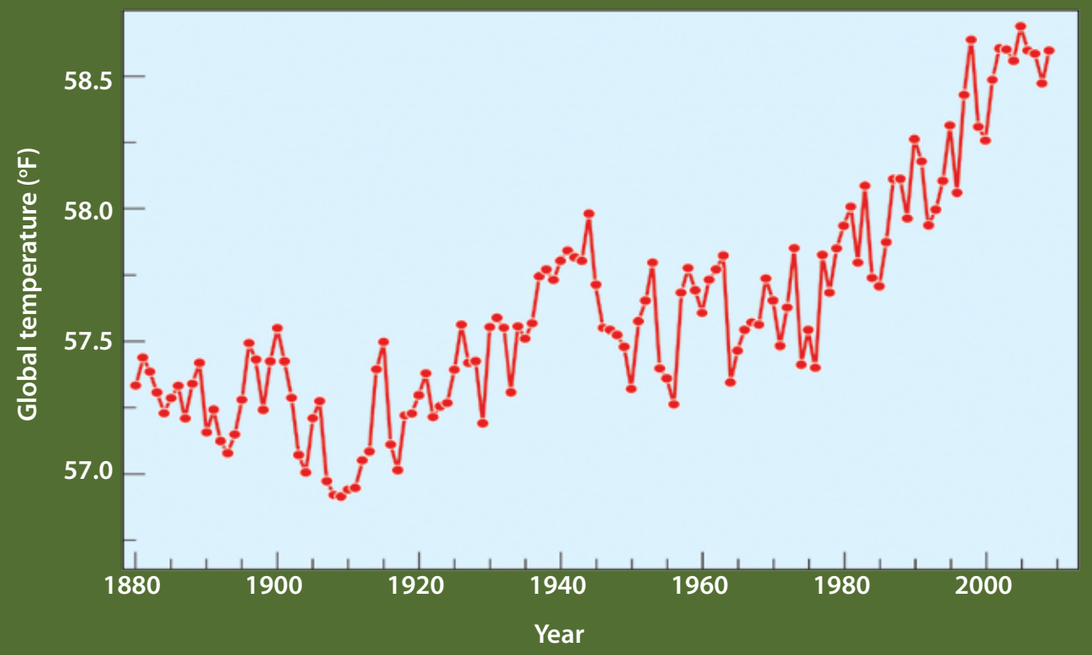
WHAT IS CLIMATE CHANGE?

Many times in our planet's long history, Earth had a much colder climate than today. During an Ice Age, huge glaciers cover large amounts of land on continents. For example 20,000 years ago the area where New York City is located was covered by ice that was about 9,000 feet thick. The ice was six times taller than today's tallest buildings. So much of Earth's water was locked up in ice that the sea level was about 360 feet (120 meters) lower than today. Your island would be much bigger if today's ocean was that low.

Sometimes in our planet's long history, Earth had a much warmer climate than today. Even the poles had little or no ice covering them. During those warm times, the ocean level was much higher than today.

We use the term global climate to describe the general climate of the planet as a whole. For the past 10,000 years, the global climate has not changed that much. Our planet's organisms have adapted to live and reproduce in the climate conditions in their locations. Different kinds of ecosystems now thrive in most of the climate conditions that exist on our planet. In addition to ecosystems, human communities have built their homes, cities, agriculture systems, and transportation systems to work well in the conditions of the local climate and geography, such as sea level.

However, the global climate has started to get warmer. The graph of average global temperature since the year 1880 shows that the global temperature has been increasing. Over the past 100 years, Earth's temperature has increased about 1.6 °F (0.9 °C). We are already seeing changes such as higher sea levels and more flooding. In this century, sea level could rise three or more feet.

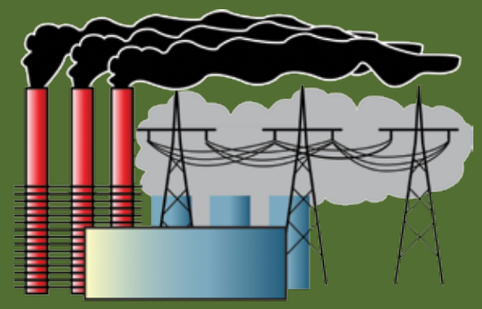


Humans did not cause any of the climate changes that happened in Earth's previous history. In contrast, the current global warming is happening mostly because we humans are burning huge amounts of fossil fuels. We use oil to make the gasoline that provides the power for cars, boats and trucks.

People also burn coal, oil and gas to make electricity. This burning of fossil fuels produces gases (especially carbon dioxide) that trap heat in the atmosphere. This trapping of heat in the atmosphere is causing Earth's climate to get warmer.

A)

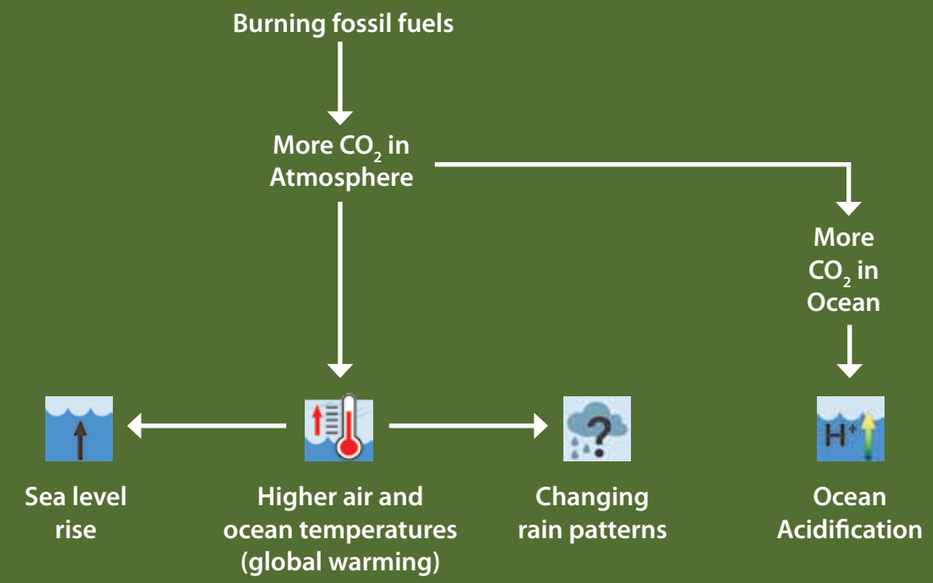
B)



When we burn fossil fuels (oil, coal and natural gas), they produce gases that stay in the atmosphere and trap heat, causing global warming. A) Oil is used to make gasoline to run cars and trucks. B) Oil, coal, and natural gas are burned to make electricity.

As shown in the diagram below, the increasing amount of CO_2 in the air is heating our planet and causing many other changes. As the ocean gets warmer, it increases in volume. In addition, melting land ice flows into the ocean and increases the volume of the ocean in that way. The resulting rise in sea level causes some of the biggest climate change problems for island ecosystems and communities.

Higher air and ocean temperatures also cause changes to the patterns of rainfall. Some places may experience more drought, while other island locations may have more rainfall, especially heavier downpours. Scientists have some evidence that tropical cyclones in the Pacific may increase in strength but occur less frequently.

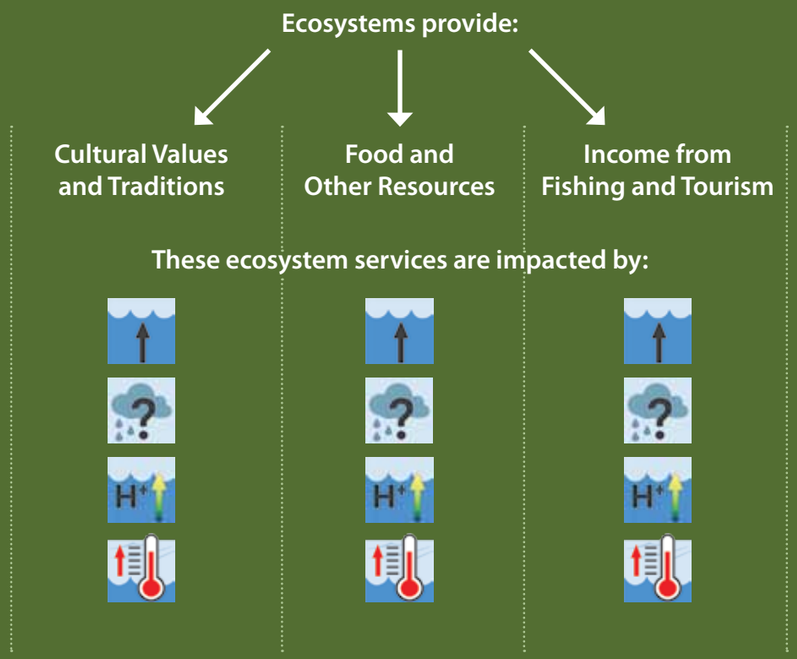


In addition, much of the extra carbon dioxide in the air dissolves in the ocean. This extra dissolved carbon dioxide forms a weak acid, and changes the ocean's acid-base chemistry. The extra acidity can harm all marine organisms that have carbon-containing shells (such as corals and clams). Because of its effects on marine organisms, this ocean acidification may be a very harmful impact of global climate change.

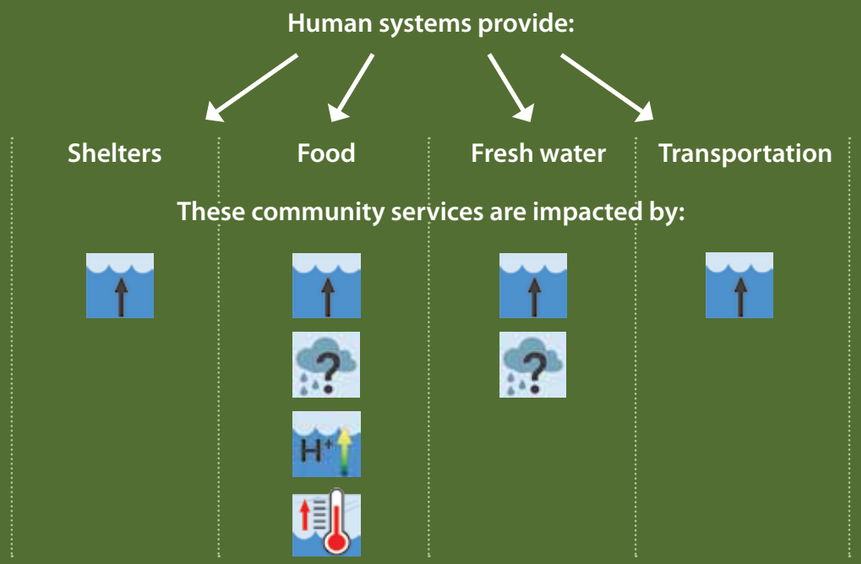
While there are other impacts of global climate change, we have focused on four impacts:

- ★ Higher air and ocean temperatures
- ★ Higher sea levels
- ★ Changing rain patterns
- ★ Ocean acidification

Each of these impacts of global climate change can directly harm at least some important island ecosystems. These ecosystems provide many services such as cultural values and traditions, food, and income from fishing and tourism. All four of the climate change impacts can decrease the benefits that humans get from island ecosystems.



We humans have been able to live in so many different places on the planet because we have developed construction systems that provide us with homes, and agricultural and fishing systems that provide us with food. We have also developed other systems that provide us with fresh water and transportation. Sea level rise can harm each of these human systems. Because of their effects on ecosystems and agriculture, all four of these climate change impacts can make it harder for people to get food. Changing rain patterns can also make it harder to have a secure supply of fresh water.



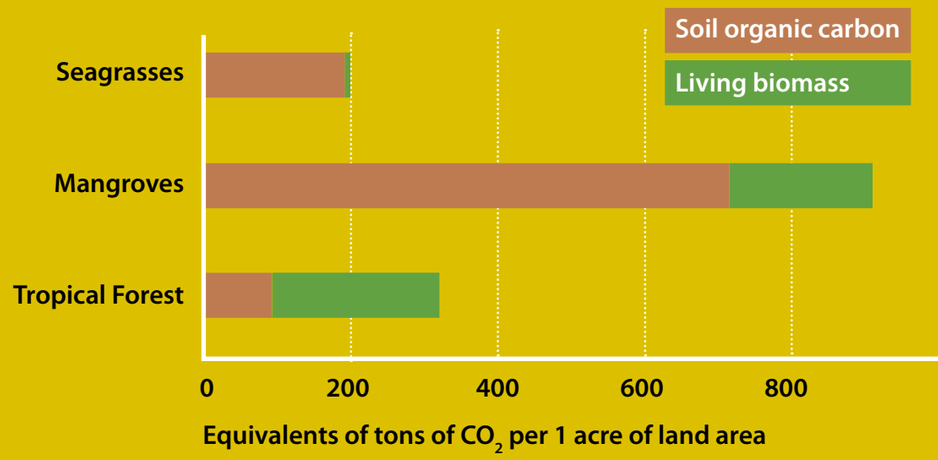
Humans can reduce the amount of climate change by burning less fossil fuel and reducing other activities that put heat-trapping gases into the atmosphere. Communities can also reduce the harm caused by climate change by planning and doing climate adaptations. For an ecosystem, the most effective climate adaptations are activities that help an ecosystem stay as close to its natural condition as possible. These climate adaptation activities mostly involve protecting the ecosystem from other human activities that can harm the ecosystem. Climate adaptation activities include preventing and removing pollution, and carefully managing fishing, cutting trees, building roads and other development. A healthy ecosystem is resilient to climate change: it tends to suffer less damage from climate change, and to recover quicker from damages that do occur.

Pages 44–49 in the main text describe the effects of climate change on mangrove swamps and ways that humans can help protect these very important island ecosystems.

MANGROVES HELP AGAINST CLIMATE CHANGE

Mangrove swamps that are in estuaries and ocean coasts provide another important ecosystem service. They are one of the best ecosystems for storing carbon and preventing it from being released as carbon dioxide into the environment. All trees have lots of carbon in their trunks and root systems, and this carbon was originally carbon dioxide that they got from the atmosphere. A healthy mangrove swamp stores even more carbon in its soil than is in the trees.

If the mangrove swamp is badly damaged or destroyed, this stored carbon can then be released into the atmosphere as carbon dioxide. By keeping all this tree and soil carbon out of the atmosphere, mangrove swamps help reduce the amount of global warming.



Source: Murray, B. et al. 2011. Green Payments for Blue Carbon: Economic Incentives for Protection of Threatened Coastal Habitats. Nicholas Institute Report.

GLOSSARY

A **Adaptation** (of an organism) – a part or behavior of an organism that helps it to survive better in its natural environment. Species have adapted to their environments over thousands of years.

Aerial Roots – roots that are in the air above the ground.

B **Biodiversity** – the number of different kinds of organisms that live in a specific place.

C **Climate Adaptation** – things people can do to help an ecosystem or their community become more resilient to climate change.

Consumer – organisms that cannot make their own food, and have to eat producers or other consumers.

D **Decomposer** – type of organism that breaks down matter that was living or came from living organisms.

Detritus – tiny pieces of food in an environment such as broken pieces from leaves in a mangrove swamp.

E **Ecosystem** – a community of all the living things in an area and their interactions with each other and with all the nonliving parts of the area.

Entangled – twisted together so it is hard to take apart or move through.

Estuary – an area where fresh river water and salty ocean water come together near the coast.

I **Invertebrate** – an animal that does not have a backbone (such as corals, worms, crabs, clams, squids, sea urchins). Animals with backbones are **vertebrates**.

L **Latitude** – distance north or south from the Equator.

M **Microorganism** – organisms like bacteria that are so small they can be seen only with a microscope.

Murky – dark and cloudy, such as the water in a mangrove swamp.

N **Nursery** – a place where it is safer for young organisms to grow up.

O **Oxygen** – a gas in the air that most organisms need in order to live. Plants make oxygen in their leaves during photosynthesis but they also need to get oxygen from the air.

P **Photosynthesis** – how trees and other plants use the energy from sunlight to make food from carbon dioxide and water.

Producer – a plant or any similar organism that makes its own food.

R **Reproduce** – how existing organisms can make young copies of themselves such as animal babies and plant seedlings.

Resilient – strong enough that the organism, ecosystem or community is damaged less and recovers quicker from difficult conditions.

S **Sediments** – small pieces of soil, rock and matter from organisms, often moved by flowing water from one area to another area where it settles to the bottom.

Species – a group of organisms that are very similar to each other and can produce young together. Generally different species cannot reproduce with each other.

T **Tropical** – locations near the Equator that are usually warm throughout the whole year.

V **Vertebrates** – an animal that has a backbone (such as fish, lizards, birds, pigs, bats, people).

TEACHING TIPS

QUICK TIPS

1. Students research local mangrove swamps and identify which mangrove species live there and compare the different species. Note that some mangrove swamps may have only one main species. Schools in different parts of the island, state or country communicate and compare their findings.

2. Students create a mangrove swamp mural. They draw and place high tide creatures and low tide creatures on the mural and explain why these creatures are found there.

3. Students describe four challenges to which mangroves need to adapt. They describe how the mangroves adapt to each of the challenges, communicating to others visually, orally, and by written report.

4. Students research what activities harm mangroves and how. They also ask what they can do with the community to restore and protect mangroves. They use their evidenced-based conclusions to communicate the effects of human activities on mangrove ecosystems. Invite families and community members to the school to discuss findings and conclusions.

5. Students investigate the role of the mangroves as a buffer/mid-zone habitat between environments on land and environments in the ocean:
   - Identify, illustrate and orally describe the interconnections between woodland, mangrove, and coral reef habitats
   - Explain the function of the mangrove swamp as the buffer zone
   - Research and respond to the question, how does change in one habitat affect the others?
   - Demonstrate through images or other media how human activity impacts these different habitats

MIMICKING STRUCTURES OF MANGROVES TO ADDRESS CHALLENGES OF CLIMATE CHANGE

Students explore how organisms have structures that are related to the functions that the structures perform for the organism. The book illustrates this principle for mangrove trees and also for other organisms that live in the mangrove swamp.

Guiding questions include:

- What are functions of the mangrove roots?
- What shapes help mangrove root structures perform these functions?
- What organism structures can we see on pages 18-19?
- How do the shapes of these structures (such as the bat's wings or the sea urchin's spines) help the structures perform their functions?

Students use their observations and explorations to design solutions to climate change challenges. For example: as the sea level rises, we will need to design houses that can withstand higher sea levels. These houses can also provide a habitat for creatures to live and be a source of food for humans. Use the mangrove roots to inspire the design of such a house.

VISUAL BRAINSTORM ABOUT MANGROVES AND THEIR SURROUNDINGS

Students use visual brainstorming techniques to help them generate ideas, record what they know about mangrove interdependency, identify questions for further inquiry, and engage in research and writing processes. They explore the idea that mangroves provide a habitat and/or nursery for many different living things and, in turn, these organisms provide nutrients for the mangroves. Students determine the interdependence between other living things and mangroves and connect that to human interactions with mangroves.

1. In small groups, students investigate topics about mangrove interdependency by brainstorming ALL of their ideas as quickly as possible. When the ideas slow down, the group tries to reach consensus about the focus of their research based on the ideas shared.

2. Students create a concept map with the main idea in the middle and then brainstorm all they know about that main idea (draw lines back to the main idea to link them) including possible areas for further research.

3. Once many ideas are recorded, review and revise the links between ideas.

4. New links and layers (sub-categories) can be added during the brainstorm process.

5. Have students add or draw visuals of the ideas represented in the concept map to help them better understand concepts and remember details. It can also provoke thinking and new ideas as they determine which visual to include.

6. Once the group's focus for their research becomes clear and is approved by the teacher, they should record the sources of information on their diagrams.

7. Now the topic focus needs to be framed for inquiry. For example, students might ask: What lives in the mangrove swamps? How do these living things give back to the mangroves? How do mangroves provide for and protect human beings?

8. The concept map is ready to be used as a graphic organizer or outline for their research.

RESEARCH FOR A LOCAL MARINE PROTECTED AREA (MPA)

A Marine Protected Area (MPA) is a location where the local government or community has developed a plan to protect the area from human activities that harm it such as pollution, development and overfishing. As the plan is implemented, the government or community keeps checking to see how well the plan is working.

This learning activity is to have students work in groups to research an existing or possible MPA for a mangrove swamp near the school or further away on the island. After doing their research, each of the student groups makes a presentation to the whole class to share their findings. If there is more than one potential local area for a mangrove MPA, the class can use the results to discuss which area would be the best to focus on, and what would be the next actions to take.

The research can focus on six important issues to analyze and discuss with respect to a mangrove MPA. These issues are:

Current Human Impacts

What human activities are already harming or threatening the area (see pages 42-43)? How could these human activities be reduced or stopped?

Expert Help

Are there local government agencies or nongovernmental organizations (such as a conservation society) that can provide expert help with developing the MPA?

Space to Retreat

As sea levels continue to rise, is there room inland for the mangrove swamp to grow? If yes, where will it most likely grow?

Soil Build-Up

How fast does the mangrove swamp build its own soil? Does the mangrove swamp build its own soil at a high enough rate to help fight against rising sea levels?

Community Experience

How has the local community worked together previously to organize and complete this kind of activity?

Mangrove Biodiversity

How many different species of mangroves does the area have? It is fine if there is only one main species, but it can be a special benefit for island conservation activities if there are more different species.

For each area, students can organize their research and then summarize their findings using a chart like the one below. The left-hand column lists the six issues described. The middle column is where students describe local conditions that help with that issue and things that do not help with that issue. The right-hand column is where students describe what other information they need about that issue. As an example, the columns for the Expert Help have been filled in.

Name of Student Group:		
Location of Mangrove Swamp:		
Issue that Affects Success	**Condition with Respect to this Issue**	**Need More Information About**
Current Human Impacts		
Expert Help	Elders in the community know a lot about the mangroves.	Which part of the government could help us? How could they help?
Space to Retreat		
Soil Build-Up		
Community Experience		
Mangrove Biodiversity		

Students recommend action steps and provide reasons for the actions they recommend.

PHOTO CREDITS

Danko Taboroši (cover, inside cover, pp. 4-5, p. 6, p. 9, p. 11, p. 12, p. 13, pp. 14-15, p. 16, p. 17, p. 18, p. 19, p. 20 - dead leaf, p. 21 - seeds, p. 21 - seedling, p. 22, p. 23, p. 24, pp. 26-27, p. 28 - sponge, snail, p. 29 - monitor lizard, mudskipper, p. 36 - mangroves, p. 37, p. 43 - destroying habitat, creating sediment, pulluting, p. 45 - ecosystem damage, p. 46 - dirtier coastal waters, p. 47 - less biodiversity, less food, p. 50, p. 51, pp. 60-61, p. 67); **Ethan Daniels**/Shutterstock (p. 10, p. 28 - sea urchin, p. 36 - seagrass); **Peripitus** (p. 20 - salt crystals); Wikimedia (p. 21 - flower); **Sengkang** (p. 21 - fruit); **Jean Yong** (p. 25 - *Xylocarpus*); **kajornyot**/Shutterstock (p. 25 - Nypa); Wikimedia (p. 28 - crab); **bofotolux**/Shutterstock (p. 28 - oyster); **Nick Hobgood** (p. 28 - worm); **Hugh Lansdown**/Shutterstock (p. 29 - bat); **nitrogenic.com**/Shutterstock (p. 29 - noddy); **Glen Fergus** (p. 29 - egret); **Paul Vinten**/Shutterstock (p. 29 - squirrelfish); **Stephan Kerkhofs**/Shutterstock (p. 29 - mullet, snapper); **Aleynikov Pavel**/Shutterstock (p. 36 - reef); **Suwatchai Pluemruetai**/Shutterstock (p. 43 - overharvesting); **Thanwan Singh Pannu**/Shutterstock (p. 45 - rising sea level); **kostins**/Shutterstock (p. 45 - changes in rainfall); **David W. Leindecker**/Shutterstock (p. 45 - destructive storms); **Julian Sachs** (p. 46 - more erosion).

ILLUSTRATION CREDITS

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OTHER BOOKS IN THIS SERIES

This book is a part of the series, Pacific Islands Climate Education Partnership (PCEP), Place-based resources for Pacific Island schools. The series also includes the following titles published thus far.

Our High Island Home is a book about natural island environments that Pacific children and their families will enjoy reading together. Highly visual images make familiar high island land- and seascapes come to life. Children living on high islands will recognize their everyday world and yet be amazed at the hidden treasures found within.

Our Low Island Home is a book about natural island environments that Pacific children and their families will enjoy reading together. Highly visual images make familiar low island land- and seascapes come to life. Children living on low islands will recognize their everyday world and yet be amazed at the hidden treasures found within.

Pacific High Island Environments is a book for those wanting to learn more about the places, plants, and animals on tropical high islands in the Pacific. The reader learns how high islands are formed and the various environments that create habitats for many species of plants and animals. From agroforests to mangrove swamps and lagoons, the reader is connected to island life and how important these environments are for the communities that live there.

Pacific Low Island Environments is a book for those wanting to learn more about the places, plants, and animals on tropical low islands in the Pacific. The reader learns how low islands are formed and the various environments that create habitats for many species of plants and animals. From atoll forests to patch reefs and the open ocean, the reader is connected to island life and how important these environments are for the communities that live there.

Adaptations—Finding a Fit in the Changing World is a book that children and their families will love. It is full of colorful pictures about how living things are adapted to meet their basic needs in the places they live. Children will be fascinated to learn that some plants have developed chemicals so that animals that share their environment will not eat them. Children will also learn that there are many different types of birds' beaks, all adapted to meet their need for getting food in different places. As children turn these pages, they quickly realize that all living things adapt to get what they need. It is this unique ability to adapt that help all living things survive.

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