South Pacific Regional Environment Programme

Training Unit C1

GEOLOGICAL ORIGINS OF ISLANDS

USE OF THIS UNIT

An understanding of the basic resources of islands must start with a knowledge of how islands are made and where they came from. This unit reviews the geological origins of the different types of islands that occur in the Pacific and gives some essential principles of their structure. As with all the units in this section on basic resources, the content of this unit can be taught in a classroom or demonstrated through examples in the field whenever these are available. Ideally both approaches should be used, but the balance between group study and practical activities in the field will need to be adjusted to the level of the participants. For participants with little academic background, the unit should be taught as far as possible through the study of examples in the field that demonstrate the geological processes or structures described in the unit.

It might assist in the retention of this material to have participants draw or copy diagrams showing the structure of the different island types, and perhaps a similar diagram of their own island. If participants have come from different types of islands, they can each describe their island to the group.

More details on coral islands are given in unit C8 Coral Reefs.

AUDIO-VISUAL SUPPORTS

A slide set illustrating the different island types accompanies this unit.

The South Pacific Commission film "Your Changing Island Environment" includes an animated sequence of diagrams showing the origins of volcanic and coral islands.

EXERCISES

One or more field visits should be organized in conjunction with this unit. The features available will depend on the island where the training is being held, but might include a volcanic crater or lava field, viewpoints where the form of the island can be seen, the shore line with cliffs or wave-cut terraces at different levels, coastal beach or rubble deposits and coral reefs, road cuts, quarries or other sites where a section cut through the topsoil and rock can be seen, caves or rocky outcrops which may show something about island structure, etc.

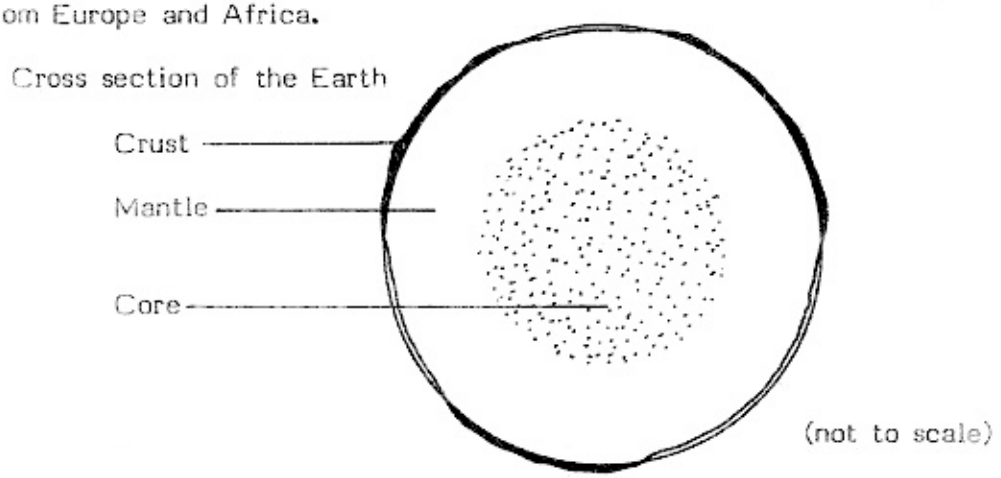
Staff from the local Department of Mines, Natural Resources or Geological Survey may be able to assist in identifying sites of geological interest and in explanating local features during field trips.

(Unit written by A. L. Dahl)
[Version 18/01/85]

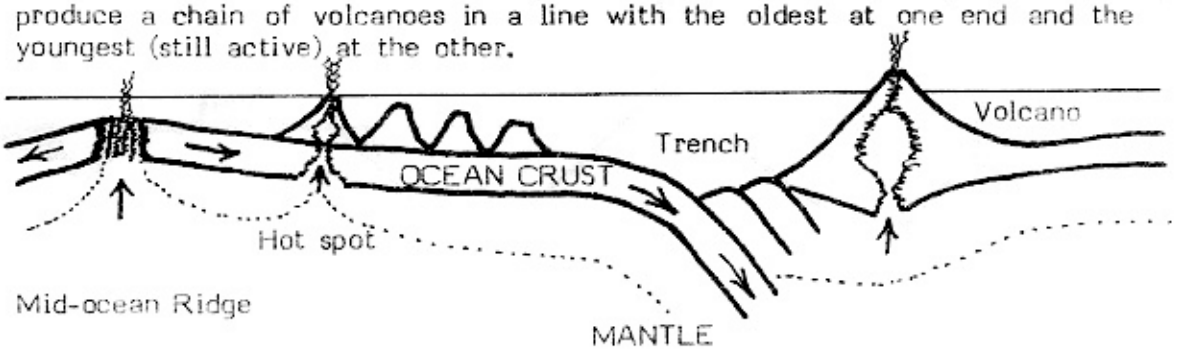
TEXT

GEOLOGICAL ORIGINS OF ISLANDS

The earth is a planet in space turning around the sun since it was born from the sun's fiery heat millions of years ago. The middle of the earth is still hot liquid rock, although the crust at the surface has cooled down enough for oceans to form and for life to develop. Even though the crust has cooled, it is not fixed in place; it is made up of plates that slowly move around. Some of the plates are of lighter continental rocks that drift around and can collide with each other. There are also ocean plates made by rock which rises up from the interior of the earth and cools, adding on to one edge, and dips down under another plate at the other edge to melt again in the interior, rather like a conveyor belt. These movements are very slow in human terms, but they do lead to important changes over geological time. For instance, North and South America are moving westward at a few centimetres per year, but this has been enough to create the whole Atlantic Ocean since they broke off from Europe and Africa.



Volcanoes are places where the hot molten rock from inside the earth comes to the surface and piles up to make a mountain. Many volcanoes occur at places where the oceanic plates are rising up or sinking down under another plate, making what is sometimes called the "ring of fire" around the Pacific. There can also be volcanoes in the middle of a plate, sometimes at hot spot where the plate is moving over a very hot place in the earth's interior. As the ocean bottom or plate moves over the hot spot, this can produce a chain of volcanoes in a line with the oldest at one end and the youngest (still active) at the other.



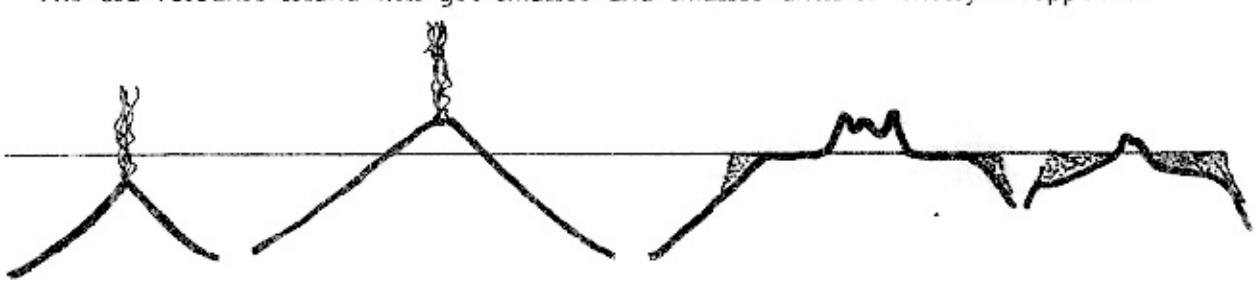
Types of islands

It is these basic geological processes that produce the different types of islands found in the Pacific.

Continental islands are pieces of continental crust that have broken off from a big continent and drifted out into the ocean. Because the rock of which they are made has come from a continental area, they can have many kinds of rock of different ages in a very complicated structure. As a result, they have many kinds of soils and may be rich in minerals. Because they have broken off from a continent, they may have carried with them plants and animals that lived on the continent at the time of their separation. New Caledonia is a good example of a continental island in the Pacific.

The other types of islands all originated from the ocean bottom and were never part of a continent. They all started as volcanoes, even if the island as we see it today has no volcanic rock left. When volcanic activity starts, it first builds a submarine volcano, erupting underneath the ocean surface. Such eruptions may produce large amounts of pumice, a light volcanic stone which floats and washes up on beaches all across the Pacific. When the volcano reaches the surface, it becomes a **volcanic island.** These islands are built of lava, which is liquid rock which spills out of the volcano and runs down its sides until if finally cools to make a hard black rock, often with bubbles in it. Volcanoes also produce ash, which is more like sand or dust which builds up in layers around the volcano. Some volcanic ash can be shot high in the air and carried long distances by the wind, where it may fall on other islands.

Volcanic islands can have different shapes depending on their age. A young volcanic island with an active volcano and frequent eruptions will be shaped like a broad cone or shield with black lava rock that goes to the water's edge and little or no lagoon or reef. As the island gets older and volcanic activity slows and then stops, the wind, rain and waves will start to erode the island, cutting into the broad shield and carrying away the softer ash deposits. The best soil will collect in the valley bottoms and along the coast. An older volcanic island will thus have jagged mountains with many valleys and steep slopes in the centre. At the same time a coral reef will build around the island, making a lagoon. The island may slowly sink as well. The old volcanic island will get smaller and smaller until it finally disappears.



Submarine volcano | Young volcanic island | Old volcanic islands

However, all is not lost for an old volcano in tropical waters, for while the volcanic island is sinking and washing away, the coral reef is growing, turning the volcano into a **coral island.** The more-or-less circular reef with a lagoon in the middle left by a sinking volcano is called an **atoll.** The coral reef (see unit C8) will keep adding material to the island, which may be piled up on the reef by storms to make areas of land on the reef. Coral islands are made of of sand and coral rock that comes from the skeletons of corals, shells and some marine plants (algae) and is composed almost entirely of limestone or calcium carbonate. Such rock is very poor in minerals, and will even dissolve slowly in fresh water.

If the sea bottom rises again, a coral reef or atoll may be lifted out of the water, making a **raised coral island,** with a platform (the old reef and lagoon) several tens of meters above sea level. Where the rain falls on the raised coral rock, it will dissolve some of it leaving sharp jagged shapes and even making caves deep in the rock. Islands like Lifou, Makatea, Nauru, Niue, Rennell and Tongatapu are raised coral islands.

The islands as we know them today may be classic types like one of the above, but more often they are mixtures of different geological structures. There are often raised reef areas on continental or volcanic islands. A lava flow may cover up a former lagoon or reef. A raised coral island like Tongatapu may be covered with rich soil from volcanic ash deposited on the island by nearby volcanoes.

The history of many islands has also been marked by changes in sea level and the rising and falling of the ocean bottom. These may cause islands to be partly covered up or even drowned entirely, then uncovered again. When the sea level fell during the ice ages, many islands were more uncovered than they are today. Sometimes terraces cut by waves in the shoreline above sea level or in the reef below sea level show where the water level was at different times in the past.

The knowledge of the geological history and structure of an island is important to understanding its environment and natural resources. It is the geology that determines the presence of minerals and the possibilities of mining. The geological structure has an important influence on ground-water resources and their behavior. It is the island rocks that determine the nature and composition of the soils. All of this is important to knowing what kind of environmental impacts to expect from a development project.

QUESTIONS

What kind of an island do you live on?

Is it a mixture of several kinds of geological structures?

What kind of rock did your island soils come from?

Can you tell the story of the origin of your island?

What do you think will happen to your island in the distant future?

ANNEX

Island Types in the Pacific

SLIDE SET

This slide set illustrates the major types of islands in the tropical Pacific as determined by their geological origins.

	SLIDE	DESCRIPTION
1.	Title	There are four major kinds of islands in the Pacific, although any individual island may be intermediate between or a mixture of two or more types.
2.	Continental island	Continental islands are made largely of continental rocks, and are on a piece of continental plate that has separated from one of the big continents. They are usually mountainous, as this view of New Caledonia shows, and their geology is very complicated.
3.	Volcanic island	When a volcano grows up to the surface from the ocean bottom, it makes a volcanic island. A young volcanic island is shaped like a shield or cone as this view of Tahiti shows. Usually there are one or more volcanic craters in the middle from which the eruptions of lava and ash build the island if the volcano is still active.
4.	Eroded volcanic island	When a volcano stops erupting, the rain and waves start to wash the island away. The soft outer ash and rock wash away first, leaving the harder rock in the centre of the volcano sticking up very steeply. In the distance you can see Moorea, which is an eroded volcanic island.
5.	Mountainous interior	The middle of an eroding volcanic island may have steep mountains and narrow valleys. This is a view of the centre of Tahiti.
6.	Black sand beach	Where the ocean washes directly against the volcanic island, it makes black sand beaches from the volcanic rock, as here on Tahiti.
7.	Fringing reef	Usually, however, a coral reef starts to grow around the island. A fringing reef like this one around Rarotonga produces white sand for the beaches.

8. Lava cliffs

If the volcano is still active, the lava may even run out over the fringing reef. This is what happened here in Western Samoa.

9. Barrier reef

The reef around the island will continue to grow as the volcano washes away or slowly sinks. As the volcanic island gets smaller, the reef becomes a barrier reef with a lagoon between it and the island. Sometimes low coral islands may be made by sand and rubble thrown up on the reef by waves, as has happened here on Wallis.

10. Atoll

When the reef keeps growing and the volcanic island disappears entirely, the barrier reef and its low islands left around an empty lagoon, making an atoll like Butaritari in Kiribati. Some atolls are very old, with reef rock hundreds of metres thick on top of the old volcano.

11. Raised coral island

If the ocean bottom rises, a coral reef or atoll may be lifted out of the water to make a raised coral island. These islands often have a lower area in the middle that used to be the lagoon, and a higher coral rim with steep cliffs dropping down to the sea, as here on Niue.

12. Coral island

Since raised coral washes away slowly in the rain, such raised islands as these in Palau are very jagged and full of holes and caves. Volcanic or continental islands may also have reefs that have been lifted up to make raised coral platforms.

South Pacific Regional Environment Programme

Training Unit C2

WATER AND THE WATER CYCLE

USE OF THIS UNIT

Water is essential to life and therefore to the environment. Many environmental problems are associated with water in one way or another. This unit explains why water is so important, and how it comes to and moves through the island system.

We have contact with water in our daily life in so many ways that we seldom give it a thought. As part of this unit, the participants should try to think consciously about the water all around them, and fit the different parts of their experience together into the water cycle. They should try to follow the water through all the parts of the water cycle in their mind.

Each participant can be provided with the text and illustrations, or the information can be presented to the group with the aid of large scale drawings in front of the group on a blackboard or with felt pens on large sheets of paper. It may help to have each person copy the diagrams.

AUDIO-VISUAL SUPPORTS

The South Pacific Commission educational film "Your Changing Island Environment" includes diagrams explaining the water cycle.

EXERCISES

The general principles in this unit need to be applied to the specific local situations of each participant's home area. If visits to some of these areas are possible, then they should include the water catchment, an examination of the local water supply and distribution system, and possibly a look at where the water goes after it has been used.

The participants can also prepare diagrams of the water cycle in their own village or area, including the specifics of their own water supply.

(Unit written by A. L. Dahl)
[Version 06/03/85]

TEXT

WATER AND THE WATER CYCLE

Water is one of the most common substances on the planet. The sea is made of water; the land contains water in many forms; the air contains water vapour which makes clouds and rain. Our bodies are made mostly of water, and if we do not drink water or other liquids containing water every day, we can quickly die of thirst.

All living things depend on water, including plants, animals and even microbes. Where there is no water, there is only a barren desert of rock and sand.

Water has qualities which make it a good material to support life. It is liquid at the right temperatures for most things to live. It can absorb lots of heat, and thus helps to even out extremes of hot and cold. Many things will dissolve in water, so that water can wash things clean or wash them away, or let many things be mixed together. In this way, the many substances that make up life can come together in water. This quality can be useful, as when it permits water to bring minerals to plant roots, but it can also be bad for the environment when water becomes a carrier of pollutants.

Most water on earth occurs in the sea. In the hundreds of millions of years that the sea has existed, many salts have dissolved and collected in it. There is too much salt in sea water for most land plants and animals to be able to use it. Life on the land needs fresh water without much salt, and this water comes through the water cycle.

The water cycle

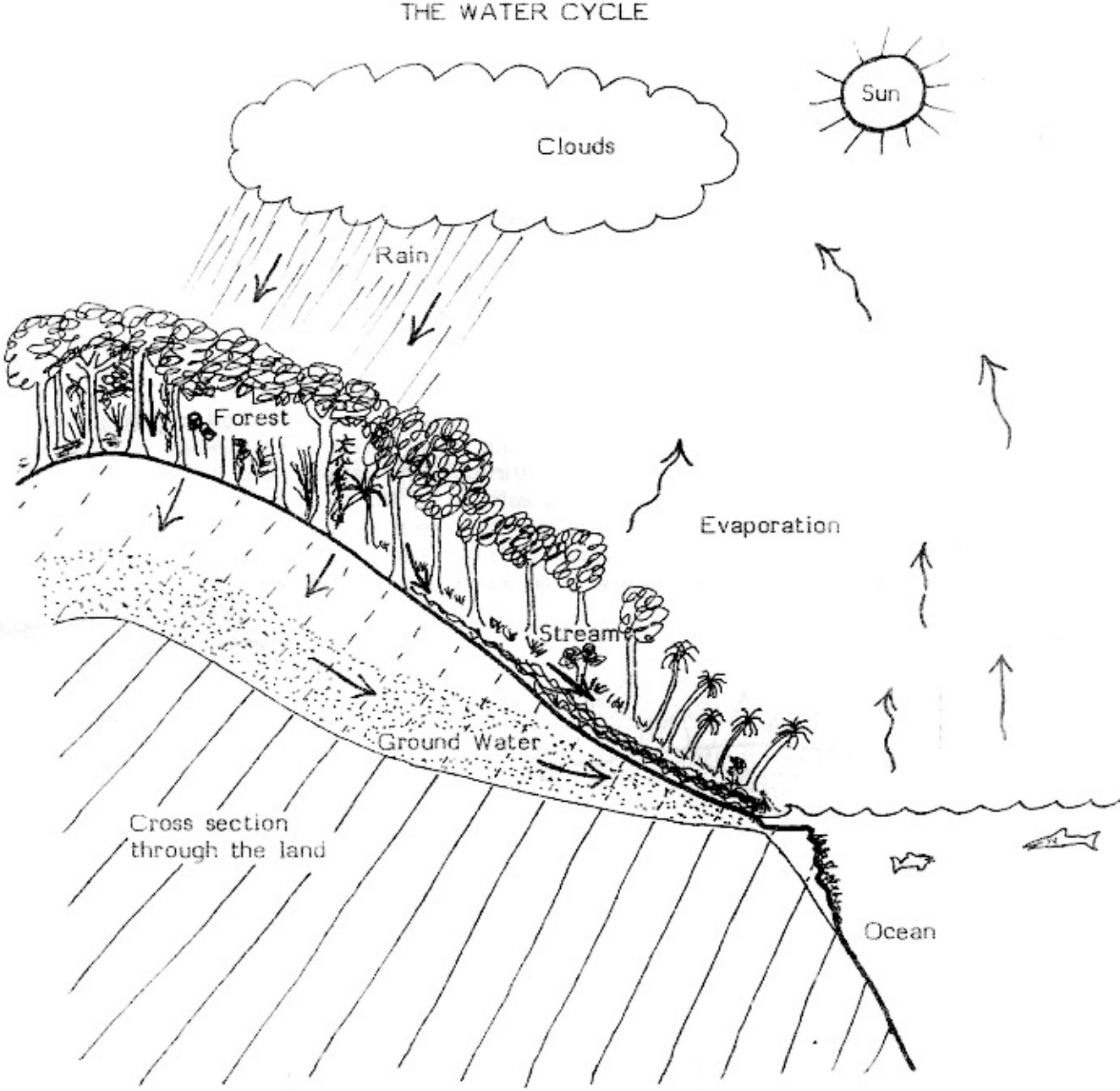
The water cycle describes how water moves from the sea to the air to the land and back to the sea again. The energy from the sun heats the ocean surface causing evaporation, which is when some molecules of water escape from the water's surface and become water vapour in the air. The salts stay behind in the sea. The warmer the air is, the more water vapour it can hold. As the sun shines and the wind blows over the ocean, the air warms and becomes full of water vapour. Warm air tends to rise, or it may be pushed up by passing over an island or other land. As it rises it cools until it can no longer hold all the water vapour in it. The water vapour condenses to make tiny drops of water which we see as clouds. If these small drops get crowded and keep bumping into each other, they become larger and larger until they are heavy enough to start falling as rain.

Some rain falls back into the sea, but much of it falls on land. What happens to it there depends on the nature of the land and the environment. If the land is sloping and unprotected, the rain water runs quickly down hill into rivers or streams and back into the sea.

If the land is covered by plants and trees, the fall of the raindrops is softened by the leaves and branches. The plants, dead leaves and soil soak up the water like a sponge. Some water is taken up by the plant roots and

evaporated through the leaves, and some evaporates directly from the soil, going back to the air. Some of the water runs off the land, but more slowly because of all the plants. It feeds the streams and rivers and keeps them flowing. More of the water has time to sink down into the ground where it becomes ground water that supplies springs and wells. The ground water also moves very slowly down hill until it too returns to the sea, completing the water cycle.

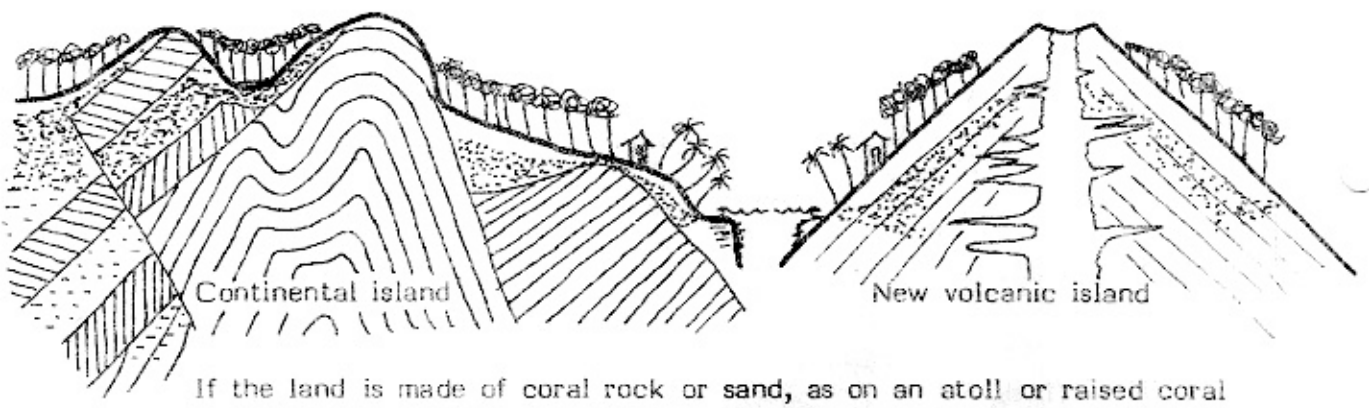
THE WATER CYCLE



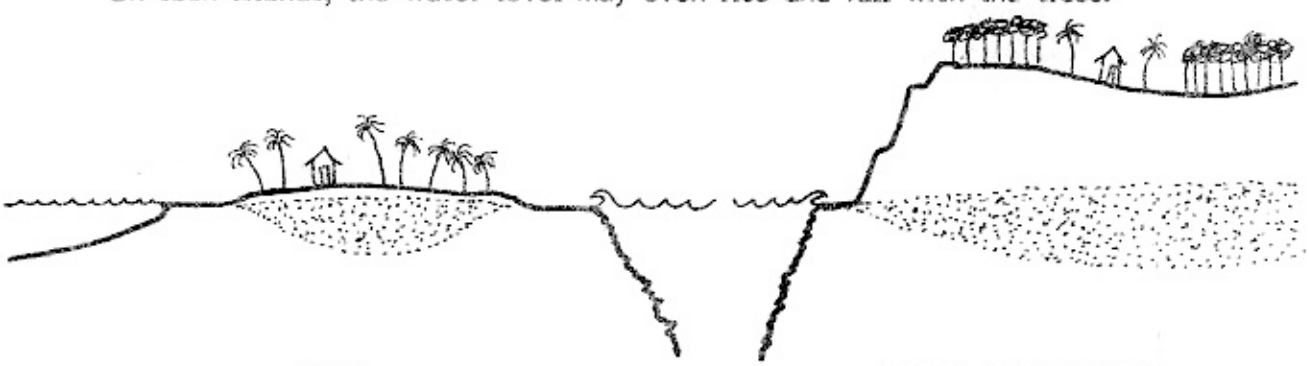
Thus the amount of water that stays on the land, and the speed with which the water cycle is completed, depend on the quality of the natural environment. In the islands, the water behaves differently depending on the kind of island and its structure.

Surface and ground water on different island types

If the land is continental or of old volcanic origin, there may be layers of rock or clay in the ground through which the water cannot pass. The movement of the ground water can therefore be very complicated, with the water moving over or collecting between these layers as it feeds streams and springs. A new volcanic island may have many tunnels, holes and layers of ash through which the water can seep away very quickly. Such islands may not have any streams that flow except in heavy rains.

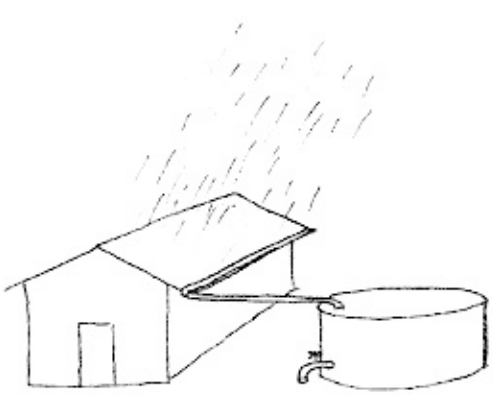


If the land is made of coral rock or sand, as on an atoll or raised coral island, there are many holes so the rain water sinks in very quickly. On such islands, the sea water goes right through the island, and the fresh water, which is lighter because it has no salt in it, floats in a layer on top of the sea water. The fresh water layer may be like a lens, thicker in the middle and thin at the edges, where it gradually flows into and mixes with the sea water. On such islands, the water level may even rise and fall with the tides.

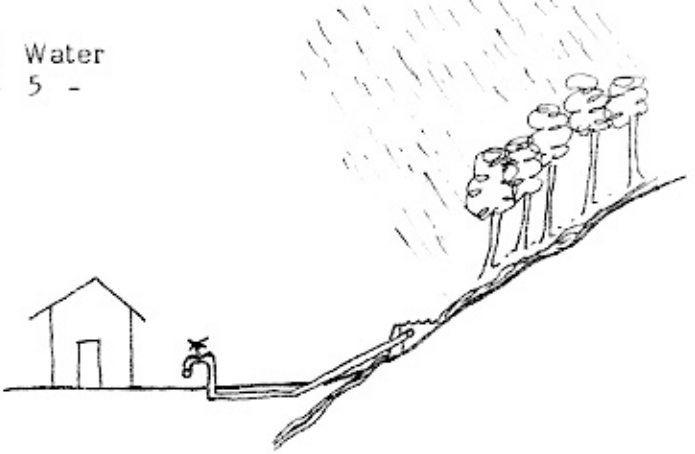


Water supplies

People living on an island may get their water at different points in the water cycle. Sometimes the rain is caught directly on roofs or other surfaces and stored in tanks or cisterns; it is important to store enough water to last through any period without rain. Where there are streams or rivers that flow all year round, the water may be taken directly from the stream as needed. If the stream stops flowing in the dry season, then a dam or reservoir will be needed to store enough water for the dry period.



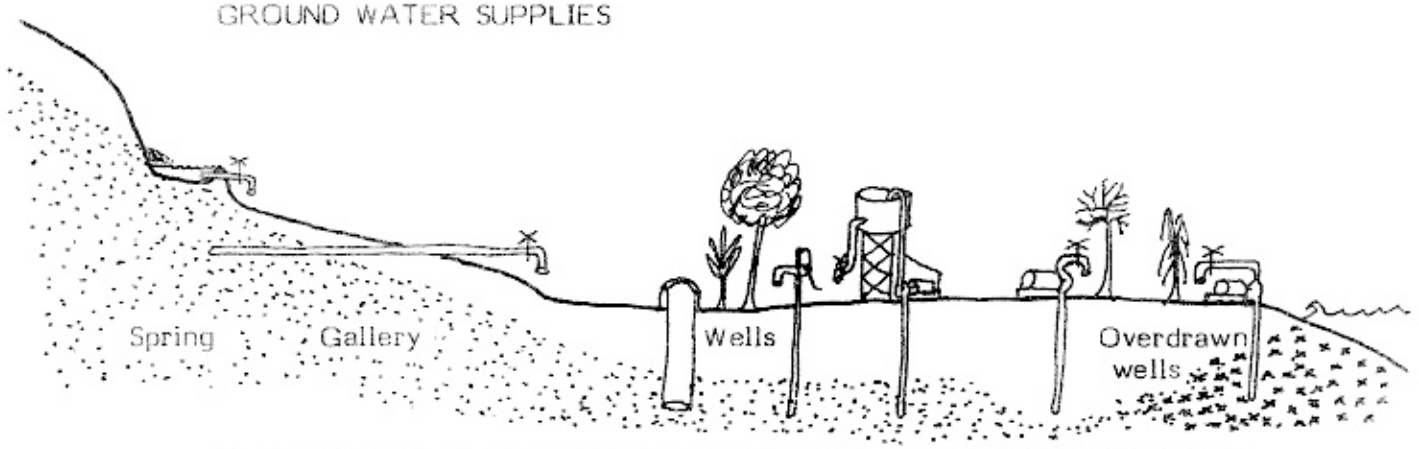
Rainwater catchment



Stream catchment

The ground water may be an important part of island water supplies, either through natural water holes or springs, or through wells dug down to the level of the ground water. Where wells provide water, they must be used with care. The capacity of a well depends on how much ground water there is, how rapidly it is replaced by new rain water sinking into the ground, and how quickly the water can move through the ground to replace what is taken from the well. If a well is near the sea, pumping out too much water may cause sea water to be drawn into the well. If a well on a coral island is too deep or is used too much, it may pull up salt water from underneath the fresh water lens. Once a well becomes salty, it is very difficult to get it to produce fresh water again; a new well will be needed somewhere else.

GROUND WATER SUPPLIES



It is important to remember that the amount of new ground water and the flow of rivers and streams all depend on the proper protection and management of the environment at the surface. If the plant cover is changed or the land is developed, the water supply of the area may be affected. Many islands now have water shortages they did not have before because of damage to the environment in places where the rain water is caught. Remember also that ground water, like surface water, tends to flow from the middle of the island towards the coast. Water supplies and wells should therefore be inland of anything that might pollute the water.

Each island is different and has its own special characteristics affecting its water supplies, but the general principles described above should help you to understand why the water behaves as it does in any local situation. Water is one of the most important island resources, and it must be managed carefully if it is to be protected.

QUESTIONS

Where does the rain come from?

Where does the water on your island go to?

What would happen to your island if the rain stopped?

What does the forest do for the water?

What kinds of water supplies do you have on your island?

Is there enough water?

If not, why not?

What could be done to make more water available?

Has development created any problems for your water supply?

What needs to be done to protect your water supply?

South Pacific Regional Environment Programme

Training Unit C3

SOILS

USE OF THIS UNIT

This unit introduces one of the most basic natural resources: soil. It is important that this unit be well understood, as soils are significant to many environmental problems, and a basic knowledge of soils is necessary for many of the units that follow.

The text should be covered in one or more group sessions, using the poster and any other audio-visual supports that may be available. Most departments of agriculture have someone with a good knowledge of soils who could come and discuss local soils and soil problems with the group.

AUDIO-VISUAL SUPPORTS

The poster-sized Environmental Fact Sheet on soils accompanying this unit can be put on a wall or passed around to illustrate the main points on this topic.

If soil maps or land use maps are available for your country, they can be used to help each participant relate the soils he or she knows from personal experience to the overall soil patterns in the country.

A video-cassette "Understanding soil" is available from the South Pacific Regional Environment Programme to illustrate this unit. It shows very simply the composition of soils and their properties, how soils are made, how they are lost or degraded, and what can be done to protect or improve them.

The South Pacific Commission educational film "Your Changing Island Environment" gives simple diagrams of nutrient cycles and soil loss for school use.

EXERCISES

A field trip to give first-hand experience with different soil types and soil management problems is the best way to present this material. The trainees should look at, dig up and examine as many different types of soil as are readily available. Soil profiles can often be observed at road cuts or construction sites. Areas of undisturbed forest soil, recently cleared soil, soil subjected to heavy use, pasture land or savanna, degraded soil, and soil erosion should be visited if possible. An agricultural officer, instructor or extension worker might be able to accompany the group to provide detailed local explanations.

SUPPLEMENTARY MATERIALS

Depending on the nature of the training programme, related units on erosion and soil degradation, soil analyses, and agriculture and forestry impacts, could be used to supplement this unit.

(Unit written by A. L. Dahl)
[Revised 16/06/85]

TEXT

SOILS

The soil is one of the most important resources in any country or island, for it is the basis of all agriculture. All our important crop plants and trees require soil, as do the forests, grasslands and other kinds of natural vegetation that clothe our islands. The nature and quality of the soils determine island productivity and development potential. Unfortunately, soils do not always stay the same. They can be improved, but usually if they are neglected or misused, they can deteriorate and lose their good qualities. It is therefore important to learn something about soils and how to care for them.

Origin of island soils

There are three kinds of islands in the Pacific, continental, volcanic and coral, and each has its own particular kinds of soils. Continental islands are fragments of rock separated off from a big continent like Australia. They usually have many kinds of rock, and thus many kinds of soil. Volcanic islands were built by molten rock (lava) coming up through the earth's crust; the lava either pours out and becomes rock, or is blown out and forms ash or loose sandy material. Coral islands are built of the accumulated skeletons of marine animals (mostly corals) and plants (coralline algae). These skeletons, like our bones, are made of calcium carbonate which makes limestone.

When rock is exposed to the weather and to attack by plants and animals, it breaks down very slowly to make soil. The qualities of the soil depend on the rock it is made from. The quantity of soil depends on how old the island is and how long it has been exposed to weathering.

Good soil is not just of mineral origin. It also contains organic matter from dead plants and animals. Leaves and other dead things fall on the ground and decay, leaving tiny fragments that are mixed with the soil. Rich soil also contains many living things: microbes, molds, worms, insects, algae, etc. This soil community keeps the ground aerated and mixed, breaks down dead material to release their nutrients, and sometimes even fixes nitrogen to make nitrate fertilizer.

Forest soils are especially good because the dense cover of living things builds up a rich soil layer, but these good qualities may not remain if the forest is removed. Many tropical forests hold their nutrients in the plants; any nutrients lost from decaying material is immediately taken up again by the dense root systems at the surface. If the plants are removed, the nutrients may quickly wash away.

Qualities of good soils

A good soil for agriculture or other human uses should have a number of qualities regardless of its origin. Physically it should be a good rooting medium, neither so hard and dense that roots cannot grow through it easily, nor so loose that they pull out easily. It should have available adequate

quantities of the basic plant nutrients: nitrogen, potassium and phosphorus. The trace minerals should also be present and well balanced, without any high amounts that might be poisonous. It should be neither too acid nor too alkaline. A good soil should also contain organic matter or humus, as this improves the texture and water-holding capacity of the soil, and assists in the availability of nutrients. Finally it should have a community of living organisms: bacteria and fungi to break down rotting matter and release the nutrients in it; fungi (mycorhyza) that help some plant roots take up materials; nitrogen fixers that take nitrogen from the air and convert it to chemical forms available to plants; worms and other animals that aerate and rework the soil; etc.

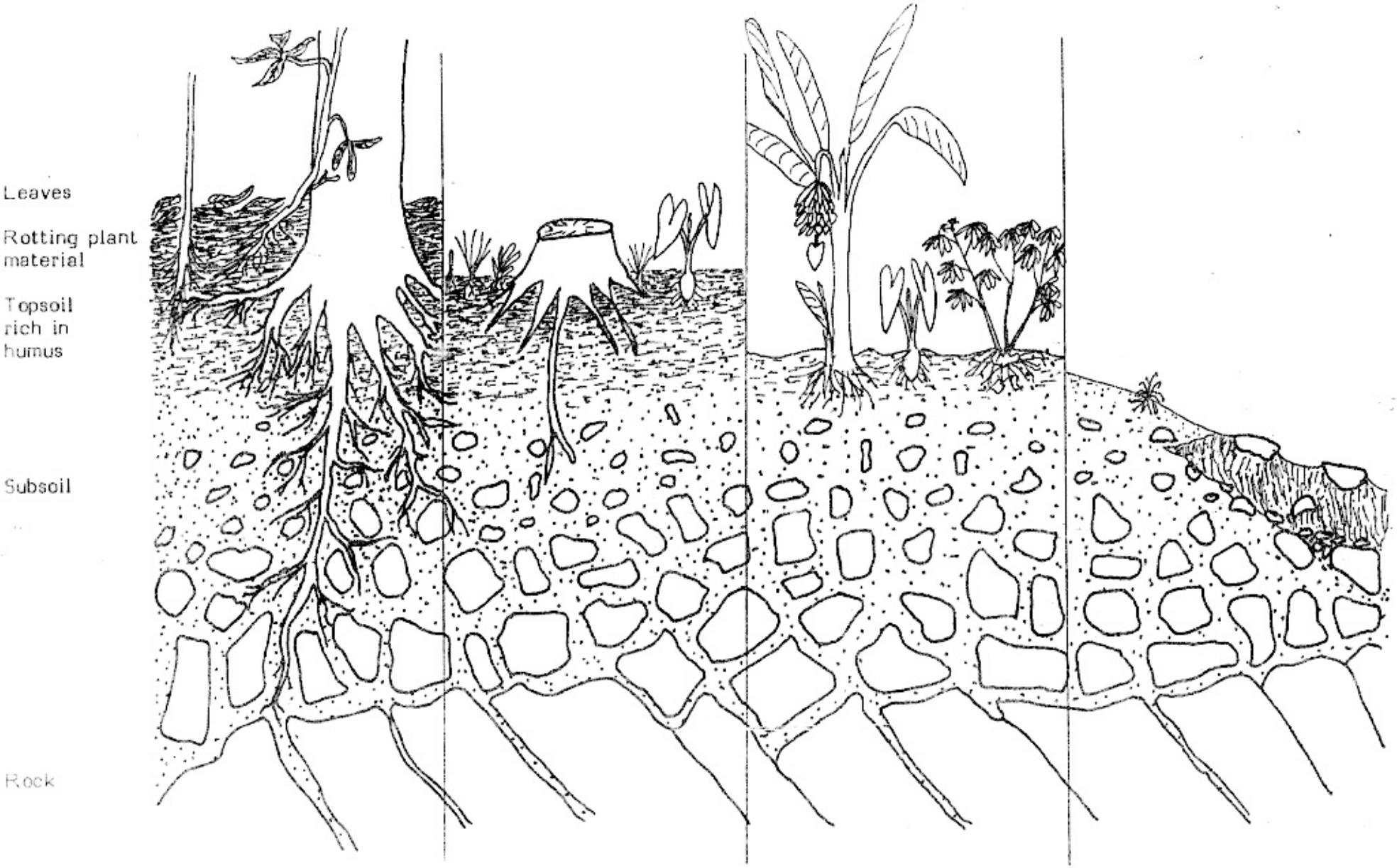
Problems of soil degradation

Even a good soil may not stay that way if the conditions under which it was formed are changed, such as by cutting down the forest. One of the most important aspects of agriculture is learning how to keep a good soil productive. The following are some of the problems that can destroy soils in the Pacific Islands.

When plants or crops are grown in a soil, their roots take up nutrients and minerals needed for plant growth. If the plant dies in place and rots, these materials return to the soil, but if these plants of parts of them are harvested and taken away, those materials are lost to the soil. The more intensive the agriculture is, the more is lost from the soil. The organic matter in soil is also constantly being broken down or used up, and harvesting a crop takes away organic matter that would normally go to replace what has been lost. This is why farming exhausts the soil, and the soil needs to be "rested" or left in fallow to recover. A poor soil may be exhausted after a single crop.

Using fire to clear the land or burn weeds also damages the soil. At first things may seem to grow better because nutrients in the plants are quickly made available in the ashes. However, these nutrients lying on the surface are also more easily blown away or washed away by the rains, finally leaving the soil poorer than it was before. Burning also destroys the dead leaves and rotting wood that would go to replace the organic matter in the soil; it can even burn the organic matter and the useful soil animals in the top layers of the soil itself. The result is a soil that can no longer hold water or nutrients and that dries out quickly.

In nature soils are almost always covered by forest, grassland or other kinds of plant cover. If this protective layer is removed (by logging, clearing for agriculture, construction, forest fire, etc.), the soil is exposed to erosion, which is the removal of the soil by water or wind. When the soil is dry, it easily turns to dust, and the wind can pick up the soil particles and carry them away. On an island, this dust is usually carried out to sea where it is lost. The rain falling on the bare soil also loosens it, making mud or muddy water that runs off the land, carrying the soil away. The running water itself is no longer slowed by plants, and cuts into the land, making ravines and gullies. In extreme cases all the soil can be washed away, leaving bare rock, but more often only a little layer is lost each year, and people do not realize that their good land is disappearing.



CHANGING SOIL PROFILES WITH LAND USE OR MIS-USE

Forest soil | Newly cleared | Heavily farmed | Eroded

Erosion can occur even on flat land, but it is made much worse when the land is sloping. The steeper the slope, the greater the danger of serious erosion, and the more difficult it is to apply effective control measures.

A little erosion is natural and normal, but it is usually very slow and the soil lost is replaced by the new soil that is slowly but constantly being made. When the natural plant cover is damaged or the land is developed, erosion goes much faster and this balance is lost.

Erosion not only damages the land, it hurts other resources as well. The mud and silt washed off the land become a pollutant, dirtying streams and water supplies, filling up dams and harbours, and smothering lagoons and coral reefs.

Certain kinds of tropical soils are also subject to laterization. The heat of the sun on the bare soil, combined with the rains washing out certain minerals, leads to chemical changes turning the soil into a hard rock-like pavement almost like concrete.

Inappropriate cultivation techniques can also damage certain soils. On Niue, where a thin volcanic ash soil rests on a coral limestone base, disking mixed the limestone with the soil, reducing its acidity and damaging its fertility.

Some low-lying island soils and agricultural areas are vulnerable to salinization or contamination by salt-water, either by flooding by the sea during storms or by sea-water infiltration into the ground water due to drought or overextraction from wells.

Urbanization results in a significant loss of areas of productive soils, since many towns and villages are located in the best agricultural areas. Spreading roads, houses and industrial developments eat up land formerly used for agriculture.

Signs of soil damage

A close look at the soil will often show signs of what is happening to it. If there is still some well established forest near by, dig a little and look closely at the forest soil, and then compare it with the soil outside the forest. The first sign of soil degradation is the disappearance of the soft moist layers of rotting leaves or humus. As a soil loses its humus, it gets harder, often lighter in colour, and dries out more rapidly.

A soil that is exposed to rain will lose its smallest finest soil particles first. If erosion carries away the fine soil, a thin layer of sand and pebbles may be left on the surface. Such a layer of coarser grains, sometimes left in rows or streaks sorted by size, is a good sign of water or wind erosion. In areas of recent rapid erosion, such as newly cleared or worked land, rocks or pebbles in the soil may be raised up on little pedestals where they have protected the soil under them while the soil around them has washed away. The height of the pedestals will give some idea of how much soil has been lost.

As erosion gets heavier, especially on slopes, the running water may cut gullies or ravines in the soil. As the water washes soil out of the bottom of the gullies, the sides and top are gradually undercut until pieces break off and fall in. Such gullies can thus creep gradually up hill, eating into the land and destroying the vegetation and the land surface. Similar erosion can sometimes be seem where road cuts, other construction, or mining have cut into hills or slopes. Plants and trees with their roots exposed are a sign of this type of erosion.

Trends in island soils

The review of the state of the environment in the South Pacific conducted by the South Pacific Regional Environment Programme demonstrated that problems of soil erosion and loss of soil fertility occur in nearly every country of the region. Since the natural processes of soil formation are very slow, this means that island soils are steadily losing their productivity. Soil productivity is essential for agriculture, so the ability of the land to provide food and other materials is decreasing at the same time that the needs, both for development and often for a growing population, are increasing. Unless the decline in soils is stopped, the future will not be very bright.

Niue is one country where it is possible to estimate the speed and importance of soil degradation. Two land surveys were made in 1949 and 1971, and each estimated the amount of degraded land among other uses. The percentage of the island surface on which the soil was classified as degraded increased from 20 to 45 percent in the 22 years between the two surveys. On a small island where resources are limited, such a loss is of great importance.

Imported agricultural techniques are not always well adapted to tropical island conditions, and can thus unintentionally speed up soil damage. It has been estimated that much of the productivity of the land in New Caledonia was destroyed in the first 50 years after European colonization, primarily as a result of extensive cattle grazing and the abandonment of traditional agricultural systems. There is evidence that many islands in the region have suffered similar problems.

Since agriculture is an essential support for most island societies, the trend towards continuing and sometimes increasing soil loss must be reversed. This will require both the better management of existing soils to prevent further degradation, and measures to restore degraded lands to productive use. It will not be possible to achieve instant results, but future generations will praise the foresightedness of those who make the effort today.

What can you do to improve soil?

Since much soil damage occurs when the soil is exposed to sun, wind and rain, keep the soil covered by plants as much as possible. This might involve planting in strips or mixing complementary crops; using appropriate ground covers, some of which actually improve the soil; planting along contours on slopes, with retaining walls, stone-lined channels and other works to prevent erosion in heavy rains; using wind-breaks and other shelter

plantings to prevent wind and rain damage; agroforestry in which tree plantings are mixed with other crops, etc. Many of these techniques were already in use in traditional agriculture, where the importance of preserving the soil was widely appreciated.

Good soil is rich in organic matter, but this is quickly lost in the tropics unless it is continuously replaced as it is in the forest. Where land is developed for other uses, it is necessary to add organic matter to the soil. Leaves, trimmings and other plant material can be composted, or put in a pile with the proper conditions for its rapid conversion into humus, which can then be added to garden soil. Cut grass, straw, leaves and other materials can be left on the surface of the ground as a mulch to protect the soil; this can then be worked into the soil later when it is prepared for replanting. Even seaweed cast up on the beach can be added to soil once the salt is rinsed out.

Any crop will remove some things from the soil, but different crops have different requirements. Soil is exhausted much more rapidly by growing the same crop over again than by rotating crops with complementary requirements. Many island soils need to be left in fallow to recover their fertility, or to be planted in a leguminous crop that fixes nitrogen. Chemical fertilizers can be used to maintain essential nutrients, but they are seldom a complete replacement for what is removed by a crop, and do not prevent some soil degradation.

Burning weeds or brush to clear the land should be avoided wherever possible for the bad effect it has on the soil. The heavy use of pesticides can also poison the soil flora and fauna which are important to maintaining its fertility and structure. The use of such toxic chemicals should be kept to a minimum, and the instructions of the manufacturer or agriculture department should be followed with care.

Good land use planning can also help to protect and maintain good soils. Soils vary greatly in their adaptability to different uses and different crops, and much soil damage comes from using the soil for the wrong purpose. A soil that is adequate for forest or tree crops may be destroyed by attempts to grow intensive cash crops or root crops. Sloping land may be best planted in tree crops, or terraced to control erosion. Important watersheds should be left in forest to protect water supplies. The different needs of the island need to be carefully balanced against the resources available in order to ensure a sustainable future.

QUESTIONS

Where did the soil on your island come from?

How was it made?

Was the land once covered by forest?

How much of the forest is left?

Is a long fallow with forest regeneration still important to keep village gardens productive?

Is there anything important missing in your soils?

Are chemical fertilizers or supplements used on your soils?

Are organic materials like plant cuttings or compost used in local gardens?

Is the soil left bare when the land is cleared, or are cut weeds or leaves left to protect it?

Is the land burned to clear it?

Are there soil erosion problems?

How much has the soil changed since your grandfather's time?

What will the soil be like for your grandchildren if present trends continue?

How much land on your island is degraded (not good for anything)?

What are some of the things you can do to solve local soil problems?

South Pacific Regional Environment Programme

VIDEO FILM SCRIPT

UNDERSTANDING SOIL

SCENE	TEXT
Title: Understanding Soil	(Music)
Written and directed by Arthur Lyon Dahl, Ph.D. Ecological Adviser	
Filmed by Philippe Huneau Wayenece Wayenece with the participation of Auguste Cidapua	
for the South Pacific Regional Environment Programme South Pacific Commission Noumea, New Caledonia	
General view of land	The soil is one of our most valuable resources.
Plants	The plants that cover the land depend on it.
Agriculture (pan to soil)	Our forests, agriculture and food plants all depend on the soil.
	What is soil?
Views of soil	It is the layer of more or less loose material that covers the rock which makes the land.
Auguste showing soil	If you look closely at soil, you will see it is mostly made up of mineral particles of different sizes, including rocks and gravel, sand, and fine silt, mud or clay.
Auguste showing humus	Another important part of good soil is the humus or organic matter that comes mostly from dead and rotting plant parts like leaves and wood. The humus helps to hold water and makes the soil rich and easy to work.

HOW SOILS ARE MADE

To understand soils, it helps to know how they are made.

Rocks

The kind of soil depends on what sort of rock it came from.

Weathering rock

Rock may seem hard and resistant, but the weather, heat and cold, wind and rain gradually break down the rock into smaller and smaller pieces.

Waves along shore

Along the seashore the constant action of the waves also helps to break down the rock,

Snails

and scraping animals break off bits of rock while eating, making sand which may pile up on the land.

Sand and rock on shore

A soil starts with these tiny pieces of rock and sand, but it is plants, and particularly the forest, that turn the bits of rock into good soil.

Grass in cracks

First small plants start to take root.

Shrub

As the soil gets deeper, larger plants can start to grow,

Plant roots in rock

and plant roots work deep into the rock, drawing up nutrients.

Forest

Eventually trees come to make a forest. The forest builds the humus, or dead plant material, that is so important in a good soil.

Leaves falling, rotting wood

The leaves that fall, and the dead plants, build a layer of rich topsoil.

Diagram: Nutrient cycle

Plants and trees grow, making wood and leaves which eventually die and fall to the ground. As they rot, the plant food in them can be taken up by the plant roots and used again by the forest. This recycling keeps the forest rich and productive. It may take hundreds of years for the forest to make good soil.

Diagram of soil section

Deep in the ground is the rock from which the soil came. Closer to the surface, the rock has broken down making the sub-soil that is mostly mineral. The top-soil is usually darker from the humus that makes it rich, and is alive with animals, molds and microbes.

Soil section

If you look at a road cut or a hole at a construction site, you can see the soil profile, going from the dark top-soil down through the sub-soil to the rock at the bottom.

LOSS AND DEGRADATION OF SOILS

Agricultural field

When we use the soil, we must be careful of those things that might damage it.

Forest, pan to garden

As long as the original forest or vegetation that built the soil is present, the soil will remain good, but when the forest is cut or disturbed, the processes that built the soil are interrupted.

Diagram of humus in soil

One of the most important and fragile parts of a soil is its humus, the organic material from dead plants and animals that holds water and makes a soil rich and productive. This humus is constantly being broken down by the animals, molds and microbes in the soil, especially in the tropics where everything goes faster because it is warm.

Ants in soil

As these ants show, a healthy soil is a community of many living things, most of which feed on the humus.

Leaves in forest

In the forest, the humus is constantly replaced,

Bare soil in garden

but once the forest is gone, less new plant material is added to the soil. The humus will gradually disappear, and the soil will be poorer and dry out faster. The reserves of plant nutrients may be carried away with the crop,

Rain on soil

or they may be washed away by the rain, since there are fewer roots to catch and hold them.

Bar driven into soil

An exposed soil may be compacted in the rain and sun, losing its humus so that it is hard for plants to grow.

EROSION

Eroded land

The worst thing that can happen to a soil is erosion, when the soil is carried away and lost completely from the land, leaving only the bare sub-soil or rock behind. Erosion can happen in several ways. If the soil is dry and exposed,

Wind erosion

the wind can pick up the dust on the surface and carry it away.

Rain on leaves

However, in the tropics it is water that causes the worst soil erosion. In the forest, the leaves protect the soil from the force of the rain, as anyone knows who has stood under a tree for shelter.

Rain on soil

When the forest is gone and the land is cleared, the rain drops fall hard on the bare soil.

Muddy run-off

They loosen the soil particles and wash them away.

Heavy rain on soil

The harder the rain is, the more soil is lost.

Soil washing away

The water running off the bare land cuts into it and carries away even more soil.

Water in gullies

It makes gullies that eat into the good soil.

Muddy river

Even worse, what was once good soil becomes mud and silt that pollutes streams and coastal waters.

Field, pan to side

Try looking closely at the soil in your fields and gardens. You can often see the telltale signs of erosion. Sometimes there will be a layer of

Gravel from sheet erosion

heavier sand and gravel on the surface where the fine soil particles have washed away evenly. Watch for small rocks standing above the

Rock on pedestals

surface on little pedestals of soil.

Diagram of rock on pedestal

Such rocks were originally buried in the soil. The rain falling on the ground washes away the soil from around the rock. As the rain cuts deeper, the rock protects the soil under it, while the rest continues to wash away. Eventually the rock is left standing on a little pedestal of soil. You can see from the height of the rock how much soil has been lost.

Manioc, pan to soil

This field of manioc has not been cleared very long, but already several centimetres of good soil have been lost to erosion.

Badly eroded land

Eventually all the soil can be carried away, leaving a barren wasteland behind. You may know of places where this has happened, and the land is no longer any good. Any loss or degradation of soil means the destruction of one of our most precious resources, especially on islands where land is so limited. This is one of the most important problems today in the island environment, and in other parts of the world it causes suffering, famine and death.

SOIL CONSERVATION AND IMPROVEMENT

Field with crops

We can learn to use the soil and still protect most of its good qualities.

Forest

To do so, we must try to do what the forest did before.

Bare field

The bare fields of European agriculture are not so wise in the tropics.

Garden with cover

Here it is often best to keep the soil covered as much as possible to protect it from erosion and drying out. Every effort should be made to add organic matter such as leaves

Composting or mulching	or compost to replace the humus that is always being lost. The rule should be to try to put back as much as you take away from the land.
Application of fertilizer	Sometimes chemical fertilizers can help to replace what has been lost from a soil, or even to make it better, but they never replace everything.
Plowing	Turning the soil or plowing may improve aeration and control weeds, but it can lead to erosion. There are ways to protect the soil and prevent erosion.
Terraces, wind-breaks	Terraces can slow water runoff on hills, and trees planted as wind-breaks can keep the land from drying out or blowing away.
Planting tree	Where the forest has been cut, new trees can be planted to hold the soil and to replace the valuable resources of the forest.
Eroded slope with trees	Even in cases of very bad erosion, it may be possible to plant trees and gradually rebuild the protective cover of vegetation.
Hill with reforestation	The erosion scar on this hillside is almost hidden by the new forest that has been planted to protect the slope.
Field in fallow	In traditional agriculture, the forest was often left to grow back and restore the soil.
Different crops	Today, rotating different crops and a good choice of crops can slow the decline of a soil.
Soil in garden, and child	Think about the future. Your soil is fragile and needs to be taken care of for the sake of your children. You should try to pass it on to them as good as, or even better than, you found it.

South Pacific Regional Environment Programme

Training Unit C4

FORESTS AND THEIR ECOLOGICAL IMPORTANCE

USE OF THIS UNIT

Forests are or were an essential part of most island ecosystems, and this unit explains the roles they have played and should play. The text explains how forests work, what their importance is, and how they are threatened. The text can be read individually or presented to the group as one or more lectures. The group should then discuss how the different points apply to their own island and forest areas.

This unit can be used independently in areas where forests are important or where forestry projects are being considered.

The content of this unit will be of greatest interest on larger high islands. It will be of less interest to people from atolls or islands where the forest was destroyed long ago.

AUDIO-VISUAL SUPPORTS

The SPREP slide programme on forests shows the importance of forests using Solomon Island examples. The Unesco Man and the Biosphere slide programme "Man and the Humid Tropics" (MAB Audio-visual series 1), illustrates the use and misuse of tropical forests around the world, although its references to MAB activities will be of less interest in this region.

EXERCISES

The best supporting activity for this unit would be a visit to a natural forest area where the different roles of the forest can be explained and illustrated with real examples. If possible dig a hole in the ground or look at a road cut bordered by forest where the relationship between the forest and the layers of soil development can be shown.

SUPPLEMENTARY MATERIALS

For a listing of the different kinds of forest found in each part of the Pacific Islands, see the "Regional Ecosystems Survey of the South Pacific Area" by Arthur L. Dahl, SPC Technical Paper No. 179 (1980), available from the South Pacific Commission, Noumea, New Caledonia. Using the survey, it should be possible to discuss the kinds of forest in each trainee's own area.

(Based on materials by A. L. Dahl and R. Cheshire)
[Revision 06/03/85]

TEXT

FORESTS AND THEIR ECOLOGICAL IMPORTANCE

Wherever there is land and enough water, seeds will be transported and plants and trees will start to grow. In time, if conditions are right, a forest will become established. Almost all land in the tropics was originally covered by forest, and the islands are no exception. Small remote islands have simple forests of only a few species, while larger islands and those nearer to continents have richer forests.

In the Pacific Islands there are many different kinds of forest. Larger islands usually have a lowland rain forest with many kinds of trees, some very tall and others shorter. Since these forests grow on the best and most accessible land, they are often cleared first for agriculture, villages or other uses. If there are mountains, different kinds of forest with shorter trees and more undergrowth may grow higher on the mountainside. Mountain tops and ridges that are kept wet by the clouds may have a cloud forest with many mosses and other plants growing in the trees. There can also be bamboo forest, swamp forests, and riverine forests along river banks that are frequently flooded. In areas where the rainfall is seasonal, there may be forests that lose their leaves in the dry season. A special kind of atoll/beach forest occurs on atolls and on the coral rock and sand behind beaches; it is made up largely of trees that have floating seeds or that are salt resistant. Mangrove forests that grow in sea water are discussed in a separate unit.

How the forest works

The forest is made up of trees, plants and animals that together make up a complicated and productive system. The plants and trees take water and minerals from the ground, carbon dioxide from the air, and energy from the sunlight in order to grow, producing more and more plant material (leaves, wood, roots) as they do so. Many animals and insects feed on the plants or on the dead materials they leave behind. Finally molds and microbes (bacteria) eat what is left and return the minerals to the soil. Thus all the life in the forest depends on the trees; if they are gone, much less food will be produced for everything else and the system will be less productive. The trees also shelter and protect the other life in the forest.

When a forest tree dies or falls over, its place is quickly taken by young trees or tree seeds waiting underneath. Some trees are better at growing quickly in open areas where there is sunlight, filling in any gaps in the forest. Others may grow more slowly, but they often grow taller and eventually dominate the other forest trees.

Many trees depend on birds and insects in the forest for their reproduction. Bees, moths or other insects go from tree to tree fertilizing the flowers. Birds or bats that feed on tree fruits may also carry the seeds away from the parent tree to places where the young trees will have a better chance to grow. If the insects are killed by pesticides, or the birds are all shot by hunters, some trees may gradually disappear from the forest because fewer young ones will grow up to replace the old ones.

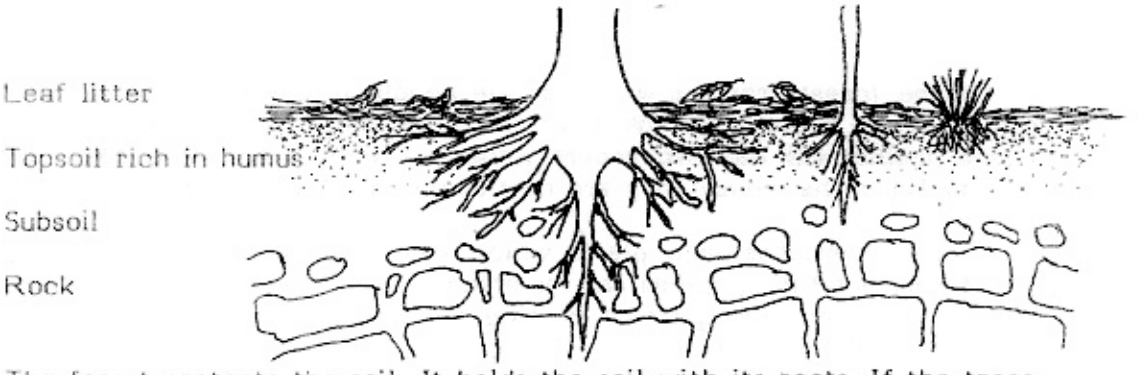
This is why the forest is called an ecosystem, because each part helps the others and also depends on the others. If something hurts any part of the system, the other parts will also be affected.

Benefits of the forest

The forest brings many benefits to the island and its people. In many ways it is the forest that made the island into a place where man can live.

The forest changes lifeless rock into a living island system. Originally, the Pacific islands were volcanos. There was just rock and sea and wind and sun. Over thousands of years the plants and animals of the forest came to the island and changed the rock and sea and wind and sun into a living cover of green. The forest grew slowly. First some plants came which were very strong and could live on the hard rock. Slowly other plants and animals followed. The forest which covers the island today is thousands upon thousands of years old. You can cut down some trees and not hurt it at all. But if you cut down too many trees all at once, you can destroy it.

The forest makes the island soil. The soil of the island is the old broken-down rock mixed with the dead plants of the forest and the many small animals and bacteria and plants which live in the soil. Forests made most of the soil of the islands. When garden soil becomes poor the forest grows over the old garden and makes the soil good again.



The forest protects the soil. It holds the soil with its roots. If the trees are cut down and no gardens are planted the soil gets hard and dry and no good for gardens. If heavy rains come and there are no trees, the soil gets muddy and washes into the sea to kill the coral reefs and ruin the fishing. Then the soil is gone and gardens will not grow on the hard rock.

The forest shelters the gardens. When strong winds and heavy rains come the trees protect the gardens. Strong winds can hurt crops and dry out the soil. Near the coast, salt spray can poison the soil or harm the crops without the shelter of trees. The forest can also protect homes and villages from strong winds.

The forest holds water. The trees and the soil they make are full of water and they store this water for times of no rain. The forest controls the flow of water over the island. When heavy rains come the trees help trap the water in the soil. They hold water in their branches, trunks, roots and leaves.

When the island is dry the water from the forest keeps the island green. Without the trees of the forest the island quickly becomes dry and the crops die.

The forest makes clouds and rain. When the sea wind blows over the island it moves through the trees and the trees put water into the wind. When the wind goes through the trees, the trees also put excess heat from the sun into the wind. The heated, wet air then lifts up because hot air rises. When the hot, wet air hits the cooler wind above the island, it makes a big cloud. No matter how hard the wind blows, the island cloud stays above the island. This island cloud is something every islander knows. In the morning the sky will be clear but as the sun warms up the trees and they add their water to the sea air, the cloud begins to form. It rises up over the island until it is so thick the bottom becomes black and heavy with rain. Then it begins to rain on the island. If you cut down the trees there may be less rain and the island may dry up; people will then not have enough water to drink or wash in and the crops will die.

The forest controls garden pests. Inside the forest many insects and birds and animals live in a balanced system. When the balance is good, the life systems work together and there are not too many of any kind of plant or animal or insect. Many of these animals and insects eat garden pests and mosquitos. When the forest dies the natural balance is lost and many of the good animals and insects disappear. In this way mosquitos and diseases can increase and gardens can be attacked by pests if the forest is cut.

The forest prevents fires. When the forest is dead the land becomes dry and can quickly catch on fire and burn away all the life.

The forest provides wood for the people of the island to use in making homes, tools, boats, carvings and fuel for cooking. If the forests are cut the island people will have to import wood for these needs at a cost of ten to twenty times the money they are now being paid for the same wood.

The forest has many plants which may be of great economic value. Not just trees, but foods, spices and medicines grow in the forest. Maybe some of the plants killed during forest cutting are worth more than the trees. When they are killed and thrown away or burned, the island may be losing plants with food or medicinal value which can never be replaced. The medicinal plants and the plants used for many generations by the island people for special purposes need the forest to survive.

The forest has some special trees of very great value, like ebony (black wood) and sandal wood, nut trees and trees which are just right for making canoes or foundations for houses or tools. While these trees are replaced naturally in the forest, they are not replanted when the forest is cut because they grow too slowly. Many trees and bushes valuable to the island people are considered rubbish by commercial loggers and these are often killed when other trees are cut.

The forest is the heritage of the island people. Treated with love and respect it will last forever and supply the people's needs. Many people in the Pacific have sacred ties to the trees and the forest that are part of their traditional cultures, and are still important to them today.

The problem of non-sustainable use

Since a healthy forest is able to renew itself, it should be possible to harvest from a forest indefinitely, in a way that can be sustained. Unfortunately today this is rarely done. The forest is mined rather than harvested. People are cutting down the forest so quickly that in a short time it will be gone from many islands. They cut down the trees for many reasons. In the past, the trees were cut down to clear the land for gardens. With modern large-scale agriculture, the forests are being cleared faster than ever. Trees are also cut down to provide fire wood for village people. As the number of people increases, the forests vanish faster and faster.

But perhaps the worst problem for many island forests is the timber industry. Trees can easily be sold for money to be exported to other countries. As long as the trees were just being cut for local use, the demand for wood was limited to what the islanders needed and could use. Most island forests grew fast enough to supply these local needs, but the export market can never be satisfied. Timber companies can easily and quickly strip the islands of their forests and still supply only a small fraction of the world's desire for wood.

Thus a forest resource which should be able to supply local people's needs forever if carefully managed is rapidly being destroyed. The most immediate and dangerous threat to the island forests is the open and limitless desire of the export market which can never be filled. Modern forestry equipment is very rapid and efficient, and many islands have already sold most of their forests to timber companies for the export market. Clearing the forest for large scale agriculture or to make pasture for livestock is the second most dangerous. Clearing the forest for gardens and firewood is also a major danger where the island population is growing quickly. The dangers to the forest from agriculture and the growing numbers of people require careful land management programmes, and this need is already recognized by most island governments.

Consequences of forest loss

It should be clear from the many benefits of the forest that its destruction can have a serious effect on island resources. The quality of the soil, one of the most basic island resources, will tend to decline, and this loss of soil structure and plant foods will mean that agriculture will produce less. There will tend to be floods after heavy rains as the water runs of the island faster, and droughts will be more frequent as rivers dry up and the water table drops during dry periods. Storm damage by wind and waves will also increase. There are also the genetic resources of the unique kinds and varieties of plants and animals for which islands are well known and which also depend on the forest for their survival. The loss of the forest means the loss of these resources which can never be replaced.

The development of forest land often brings progress in the short term. It is only after several years that the bad effects may become apparent. In areas where there is a lot of forest, obviously some can be developed wisely

without creating major problems. As an increasing proportion of the forest is lost, the effects will become more severe. Since the most vulnerable areas are often developed last, it is the loss of these last forest remnants that may be the most catastrophic for an island.

Sustainable use of forests

On islands where all natural resources are limited, it is important to make full use of those resources that are present, but in ways that do not damage their ability to keep producing on into the future. Since forests are important in many different ways, they can only be managed wisely if all the different factors are considered together. In many places a forest is seen only as a source of wood; on an island its role in soil protection and water supply regulation may be just as important.

If several basic principles are followed, it is usually possible to draw many kinds of benefits from forest areas, but this requires a good knowledge of the forest and its limits, and careful observation of the effects of any use or change on the way the forest works. Since forest trees may live to be hundreds of years old, some effects, such as on the kinds of trees that make up the forest, may only appear very slowly. It is always wise to leave some areas undisturbed as a protection against the total loss of some valuable forest resource.

The first principle for sustainable use is that any harvesting of forest resources must remain within the limits of what the forest can replace. Some trees can be cut, but enough should be left behind to re-establish the same species. If only one kind of tree is being taken, it may be replaced in the forest by other less desirable species unless special efforts are made to ensure that young trees of the same species can grow back again. The same principle of moderation applies to the percentage of forest area disturbed at any one time. Enough undisturbed forest should always remain to shelter wildlife and wild plant species and to allow them to repopulate forest that is growing back after being disturbed. Too often the economic pressures for rapid development go against respect of this principle, and the forest is destroyed or degraded.

The forest should always be left intact in vulnerable places such as on steep slopes, along stream banks and on shorelines where its importance in protecting against erosion outweighs any other value. Examples all through the islands show that the cost of repairing the damage done far outweighs any benefit from developing these forest areas.

Most forest areas can be developed for or serve several different uses at the same time. A watershed essential for a village water supply can also protect wildlife and be a place to collect fruits and medicinal plants. A forest that is carefully and selectively logged while preserving the cover of trees may continue to build and protect the soil. Sites for tourism or recreation can be developed in a coastal forest while protecting its importance in sheltering the interior from storms. What is important is to know the different values of the forest and to be certain that the uses chosen are compatible and that no essential function in threatened.

Where uses are not compatible, they can be planned for in different parts of the forest. A village may decide to leave a block of forest close to the village to supply firewood and wood for construction. Another part of the forest might be set aside for hunting, while still another might be protected from hunting to allow the birds or animals a place to reproduce.

A forest can also be used for agriculture as shown by recent approaches to agroforestry. Many crops can be grown among or between trees, so the same area of land can produce both foods and tree products. This can be especially good on sloping land where fields cleared for agriculture would be subject to erosion.

It is also possible to plant a forest specifically to produce wood or other products. Many countries have tree planting or reforestation programmes. Sometimes an area is replanted with trees after logging. Land may also be planted to create a forest again where it was destroyed long before. The trees that are planted may be fast-growing imported species like eucalyptus or caribbean pine, or other important timber species. Usually only one kind of tree will be planted in an area. They are almost always planted with the idea that they will be cut as a tree crop to pay for the investment in planting them. The native trees that originally grew in the forest are seldom replanted because they grow too slowly to give an economic return. Such forest plantations may be an appropriate use for some lands, and they may help to protect the soil and hold water, but they rarely work as well as the original forest did, and some damage is always done when the trees are cut. They also do not shelter as much wildlife or medicinal plants, nor are they as valuable for tourism, recreation or protection from storms. Where such plantations are used to restore land that has been damaged or degraded, they can make a valuable contribution to island resources. The plantations of the Fiji Pine Commission on the degraded grasslands of Fiji are an excellent example of this.

Forests must have an important place in the balanced development of any country or island for the many reasons given in this unit. Even at the local level, land owners would be wise to maintain the forest on appropriate parts of their land, or even to replant forest trees where they have all been destroyed. Making or protecting a forest is not necessarily something that will give a quick return, but it may well ensure a better future for your children and their children.

QUESTIONS

How did the forest come to grow on your island?

How many kinds of forest can you think of in your area?

What local animals, birds and insects are important in helping trees to reproduce and in spreading their seeds?

How does the forest bring water to the island?

What does the forest do to the soil, and how does it do it?

List as many benefits from the forest as you can. Can you think of some that are not mentioned in the unit?

How much of your country or island used to be covered by forest long ago?

How much forest is left today?

Will there be much forest left in 20 or 50 years from now?

What would your island be like with no forest left?

What are the things that are destroying the forest? Give local examples.

Can you give some examples of good sustainable uses of the forest?

How would you solve the problems faced by forests in your country?

South Pacific Regional Environment Programme

Training Unit C5

ENVIRONMENTAL MANAGEMENT IN AGRICULTURE

USE OF THIS UNIT

Agriculture depends on environmental resources and can only succeed if those resources are respected. This unit reviews some of the environmental principles underlying the success or failure of agriculture and livestock raising. Since the specifics of agriculture differ greatly from place to place, it will be necessary for the discussion leader to explain the application of the general principles described here to local situations using local examples. Your agricultural department or agricultural extension officer may be able to help.

Since many participants will have had experience in agriculture, it should be possible to organize a good discussion of these principles as they relate to each person's own experience. The section on agricultural strategies is intended to pose questions rather than to suggest solutions, which may depend on government policy or on the preferences and possibilities of the individual farmer.

Other units such as those on soils (C3) and the weather (D2) cover closely related topics.

AUDIO-VISUAL SUPPORTS

Local agricultural schools and extension services may have audio-visual materials which could be used to support this unit.

EXERCISES

Field trips should be arranged to agricultural areas showing both subsistence and large-scale commercial development. If possible they should be led by a knowledgeable person able to explain the environmental aspects of each type and their sustainability.

(Unit written by A. L. Dahl)
[Version 19/02/85]

TEXT

ENVIRONMENTAL MANAGEMENT IN AGRICULTURE

Agriculture involves the planting of plants or the raising of animals on the land in order to produce something useful. It means making some effort to use the land or to manage it. It can be as simple as sticking a root in the ground in a forest clearing, or as elaborate as the giant machine plowed, planted, sprayed and harvested fields of modern agro-industries.

Because we do something to the land in order to produce what we need, we take on the responsibility to manage the land and the plants and animals we put on it or leave on it. This is not the place for detailed instructions in agriculture or the economics of agriculture. Our aim is to show how the environment affects agriculture and how these influences can be used or managed to make agriculture more successful.

A renewable resource

Agriculture is often called a renewable resource because, if the land is used with care, it can continue to produce indefinitely. One of the most important roles of environmental management in agriculture is to make sure that it is truly renewable, and that the ability of the land to produce is not damaged by its use.

Agricultural development of the land often goes through stages, a first pioneering stage, then maturity, and all too often a decline. The pioneering stage is on land that is newly cleared from its natural state. The soil has generally been made fertile by the forest that was growing on it. Such virgin soil is easy to develop and will produce well without much effort. However, if care is not taken (and the need is often not seen until too late), the soil fertility will decline and much of the agricultural potential of the land will be lost, especially in the tropics where the process goes much faster. Such agriculture is like mining the land, it is used up and then abandoned. This occurs often when pioneering or colonizing peoples settle on the land. They lack local knowledge, and their early success only makes their ultimate failure more difficult.

The land and people that survive this pioneering stage may be able to develop a more mature form of agriculture adapted to the land and the environment, and much more sustainable. There are traditional agricultural areas that have been in use for hundreds of years. However, even in these areas there is the risk of a slow erosion of the top soil layer that will eventually mean a decline in productivity. The world has too many deserts and rocky hillsides that were once important agricultural areas, and the loss of agricultural land is worrying even the richest and most successful countries. Even where knowledge and experience have shown how to do sustainable agriculture, there may be economic pressures for short-term gain that prevent it.

Any damage to the ability of the land to produce is a threat to the future. At a time when populations are generally increasing and there are more and more mouths to feed, the destruction of the ability of the land to produce food can only lead eventually to famine and death.

Soils and agriculture

The soil often limits agricultural production. Only certain soils are rich enough and stable enough for regular cultivation. Other soils may be suitable for pasture or tree crops. Poor soils may have no agricultural potential, and any attempt to develop them would be a waste of time and effort. Some soils may lack certain minerals required by some crops, while others may have so much as to be poisonous to many plants.

Soils can sometimes be improved by adding fertilizers or other chemicals, or by putting in humus or other organic matter, but this is expensive and sometimes difficult to do on a large scale. It is easier to keep a soil good than to restore it once it has been damaged.

It is essential to pick crops that will grow well in your soil. Farmers used to do this by trial and error, but today an agricultural specialist or extension agent can help to choose the plants most suited to a particular soil. Even then some trials would be wise before making a major investment in planting a new crop.

Climate and weather

Each plant has temperatures at which it grows best, as well as high and low temperatures that will kill it, and these are different for each kind and variety of plant. Plants also have different needs for water which may change as they grow, and some can stand being dry or flooded better than others. It is thus the climate as expressed by the weather through the year that limits what can be grown on any particular soil.

In considering the effect of climate on crops, both average conditions and the occasional extreme are important. The closer conditions are to the ideal for a plant, the better it will grow. But only one day that is too hot or too cold may kill it. The extreme condition need not occur very often for it to be disastrous for agriculture. Cyclones, droughts, floods, and rare cold spells all can be important limits on agricultural development.

It is possible to change some aspects of the climate as they affect agriculture. Careful selection of the land can reduce the risk of wind damage or flooding. Rows of trees can be planted as wind-breaks to shelter crops. Proper drainage or the construction of rows or mounds can reduce the damage from flooding. Irrigation can provide water when natural rainfall is insufficient. The limitations then become economic rather than climatic.

Biological interactions

Almost all crop plants and domestic animals have been introduced from somewhere else, and are grown close together in large numbers. As with any large-scale introduction of an organism that does not naturally occur in a place, there is a risk of imbalances, and particularly of the rapid spread of pests or diseases.

When a crop is grown over large areas, any pest that takes a liking to it will find an abundant food supply, and will be able to multiply very rapidly. While it may be technically easier and more economic to plant large fields of the same thing, it will also be necessary to use more pesticides because the crop will be more vulnerable to attack.

The presence of certain pests and diseases in a country may limit its agricultural productivity, and the introduction of a new pest or disease from overseas can be a disaster for even a well-established agricultural programme.

There can also be the problem of aggressive weeds or shrubs that can smother gardens and crowd out more useful plants in pastures, and that may be very difficult and expensive to control.

Since island ecosystems are vulnerable to introductions and lack many natural controls that would keep pests from getting out of hand, island farmers must be particularly careful in choosing what they grow and how they grow it, and in avoiding accidental introductions. This is why countries have plant quarantine restrictions to keep dangerous pests and diseases from coming into their country.

Choice of varieties or races

Each individual plant or animal is a little bit different from others even of the same kind, and it is these differences that lead to the many varieties or races that a farmer can choose from. Each variety will do best under some conditions and less well under others. No one variety will be best everywhere.

The conditions for agriculture on an island are very different from place to place, even over short distances. These microclimates depend on the shape of the land, the altitude, the direction of the prevailing winds, whether it is the wet or dry side of the island, the distance from the sea, the surrounding vegetation, and other things. It is therefore necessary to choose the varieties that do best under your particular conditions.

This principle was well known in traditional agriculture, when many varieties were grown even by the same village. Some were adapted to different soils or fields, or even to different parts of the same garden. Some did best under good conditions, while others would survive and produce even in a bad year. Those that did not taste as good might better resist a cyclone or drought, or an attack by a pest or disease. New varieties were sometimes exchanged on inter-island voyages, or they might be discovered growing in the forest or in an abandoned field. A wise farmer compares the performance of all his plants, and selects the biggest and strongest or most resistant for use in the next planting. In this way the planting stock is constantly improved.

Today, agricultural specialists and plant breeders can cross different varieties to produce a particular set of characteristics such as resistance to disease, good response to fertilizer, good quality for marketing, etc. Such varieties are well adapted to commercial agricultural production. However, even the most highly-recommended varieties need to be tested for their suitability to local conditions. They also can be more vulnerable to unfavourable conditions, where a mixed planting of different varieties or crops would give a greater chance of at least some success.

Small scale trial planting can help to show the most appropriate varieties for local conditions. Since the weather can be very different from year to year, it may take several years of trials before a final choice is made. This takes time, but it is the essential foundation on which a stable and productive agriculture can be built.

Many agricultural projects have failed because the wrong varieties were selected, or because some pest or disease could not be controlled, or because the soil or climate were not well suited to the crop. Successful agriculture requires careful attention to all these ecological and environmental factors.

Livestock

The raising of animals such as beef cattle, dairy cows, horses, sheep or goats in pastures adds an additional complication to agriculture through the animals that feed on the plants. It is necessary to manage both the productivity of the plants in the pasture and the effects of the animals on the plants.

Plant growth in a pasture varies with the season, and there may be little or no growth during the dry season. The amount of food produced determines the carrying capacity of the pasture. The number of animals should not be more than the growth of the plants is able to feed over a full year, without the plants being all eaten up. If there are too many animals, they will graze the plants down to the roots, killing them or slowing their growth. Some plants (usually those most preferred by the animals) may disappear from the pasture. Only plants that the animals do not like to eat will increase, and these may take over the pasture replacing the good plants. As the soil is exposed by overgrazing, it is easily eroded, reducing the productivity of the pasture even more. If the pasture is too badly damaged, it may never recover.

The plants are the first to show signs of overgrazing; the kinds of plants will change, there will be fewer of them, and they will cover less of the soil. Only unwanted plants will increase. Next comes the signs of erosion: bare ground, gullies, and tufts of grass on pedestals of higher soil surrounded by lower more eroded soil. The productivity of the pasture as shown by the number of animals that can live on it may only decline after the real damage has been done.

While it may seem easiest to let the animals roam freely over a large area looking for whatever food is available, this may lead to damage of the most preferred areas. Stream banks and areas around water are particularly vulnerable. It may be better to use smaller areas of pasture, perhaps improved by fertilizing and by planting desirable species, with more frequent rotations between pasture areas.

Livestock may also contribute to soil damage by compacting the ground with their hooves, and by creating trails where gullies may start to form. Sloping ground is particularly vulnerable to erosion started by the frequent passage of animals.

In woodland and savanna areas where trees are present, livestock may eat all the tree seedlings, and thus prevent the normal replacement of the trees.

Commercial and subsistence agriculture

Traditional agriculture was almost entirely subsistence agriculture, in which food crops were raised to be eaten locally. Today most agricultural development projects are for commercial agriculture, where the produce is sold to earn money. Such cash crops are becoming increasingly important in rural agriculture.

Commercial agriculture pays best if it is done on a large scale. It often requires the use of machines which are expensive to buy and difficult to maintain. It almost always means using fertilizers and pesticides which cost money and may cause health or environmental problems if they are not used with care. The commercial market requires uniform varieties which may be more vulnerable to an agricultural disaster. All of this means a higher investment which may be difficult or beyond the reach of a small farmer, as well as a greater risk of environmental damage.

Subsistence agriculture is usually based on traditional methods which have proven themselves over hundreds of years. It uses many varieties of trees and plants, usually mixed together in the same garden but with roots at different levels to make full use of the soil while protecting it from erosion. It is done on a small scale making good use of the space available, and is thus better balanced with the environment.. It fits local social and cultural patterns, and as traditionally practiced usually provided a healthy and balanced if not very varied diet. However, it can present environmental problems if the population is increasing and too much pressure is being put on the land.

What is worse is that too often cash crops are replacing local food crops in rural agriculture. The cash crop requires an important investment, so the best land is used for it; food plants are put on whatever land is left. The first priority for labour is maintaining the cash crop, so less time is available for growing food, and the planting calendar may be changed to less desirable times to avoid conflicting with the requirements of the cash crop. Since less food can be produced under these conditions, the money earned with the cash crop goes to buy imported food. This is often less nutritious than fresh local foods even if it tastes good. Health problems like bad teeth and growing too

fat, and sicknesses like diabetes, high blood pressure and heart attacks have become big problems in the region for people who have changed from traditional to imported food. Children suffer particularly from eating too much sugar, rice, corn pops and soft drinks, and not enough vegetables and protein; they do not grow well and they are often sick.

This does not mean that commercial agriculture is necessarily bad. What is important is that a village must balance its desire for money with the need to provide proper food for its people and to be more self-sufficient. There is no reason why both cannot be done together with some careful planning.

Strategies for agriculture

The differences between modern commercial and traditional subsistence agriculture also illustrate two different strategies which can lead to conflict or failure in an agricultural project if they are not well understood.

A western agriculturalist tries to produce as much as he can. He selects the highest yielding variety and fertilizes it well; he fights off weeds, pests and diseases with the latest chemicals; machines let him plant and harvest quickly and efficiently. If the harvest is good, he covers his costs and makes a tidy profit. If there is a disaster, he requests compensation, or borrows against the next year's harvest and starts again.

Traditional agriculture evolved under different conditions. The first priority was to be sure to always have something to eat. At a time when food aid did not exist, it was essential to minimize the risk of complete failure which meant starvation. A high producing variety might be planted, but so would hardier plants able to resist bad conditions. Traditional agriculturalists are slow to try anything new, because that will increase their risks.

While it is in the long-term interest of all agriculture to preserve the productivity of the land, the short-term interests may be different. The commercial farmer must keep his costs down if he is to make money, and environmental measures may increase his costs or reduce his yield. It is natural to want to put off such measures for some other time if they do not seem too pressing. For the traditional farmer, environmental protection reduces the risk of failure, especially where the risk is greatest from a storm, flood or other catastrophe. For him it is worth while to invest in protective measures, even if it is several years before they show their worth.

There may also be a difference between the needs of the individual, for whom the first priority might be to make money for a traditional wedding or to buy a radio-cassette, and the environmental needs of the group or community, for whom preserving the productivity of the land is the best assurance for the future.

Both strategies, of producing as much as possible and of reducing the risk of complete failure, have their place. It is for each community or each individual farmer to find the balance or combination between the two that fits their goals and the alternatives (or lack of alternatives) available to them. A good discussion and conscious decision on these strategies is particularly important where expatriate or western-trained agricultural advisers are working with subsistence farmers. Both the economic and environmental dimensions of these strategies need to be well understood.

It should be clear from the above that sustainable agriculture depends on good environmental management. In practice this is never easy because agricultural systems are very complicated, many environmental factors are unpredictable and cannot be controlled, and there is much we still do not know. However, with an understanding of the principles, confidence in local knowledge, a certain caution, plenty of common sense, and a willingness to work hard, the chances of success are reasonably good.

QUESTIONS

Why is environmental management important for agriculture?

Is agriculture a renewable resource? What does that mean?

What is the difference between agriculture on newly cleared land and that on land that has been used for many years?

Why are soils important for crops?

What is the role of the weather and climate in agriculture?

What can be done to reduce the influence of climate?

How do biological interactions affect agriculture? (Give specific examples)

How do you select the best varieties for local use?

What does overgrazing do to the land?

How can you tell if pasture is overgrazed?

What is the difference between commercial and subsistence agriculture?

Why have cash crops sometimes led to health problems?

What are the differences in strategy between modern commercial and traditional subsistence farmers?

South Pacific Regional Environment Programme

Training Unit C6

FISHERIES MANAGEMENT

USE OF THIS UNIT

This unit reviews the environmental principles which can contribute to the management of coastal fisheries in the tropical Pacific Islands. It aims to help fishermen to see how catching fish can have an effect on the biological system that produces the fish. They can then see how they are themselves responsible for managing their own fishery.

Each section of the unit should be presented and discussed by the group until the point is well understood. A local fisheries officer or other knowledgeable person could be invited to explain each point using local examples and the local names for the fish and other animals.

If there are experienced fishermen in the group, they should also be able to provide many details to illustrate some of the points raised. However fishermen or others who have never been diving with a mask or goggles may find it hard to imagine what things look like underwater. In this case underwater slides, films or field excursions would help to make the unit meaningful.

The units on Coral reefs (C8), Lagoons (C9) and Mangroves (C10) provide more information on specific coastal fisheries environments.

AUDIO-VISUAL SUPPORTS

Films or slides of coral reefs and underwater life are quite widely available for general illustration of the fisherman's environment. Amateur photographers in local diving groups may also have pictures that could be used, with the advantage that they would illustrate the local situation, which is always more interesting. Local fisheries departments may also have audio-visual materials or publications with illustrations that can be shown to the group.

EXERCISES

The most effective exercise would be to arrange discussions with local fishermen (particularly older men and women) about the management of local fisheries and possible signs of overfishing. Remember that different types of fishing are often the responsibility of different groups, families or sexes, and it would be good to include representatives of each to have an overall picture. Such discussions could even take place while accompanying the fishermen on a fishing expedition.

If it is possible to take the group diving with masks or goggles, this can be useful, particularly if it is possible to visit both areas where there is heavy fishing (and perhaps overfishing) and reserves or more remote areas where there is little fishing, to see the differences in the condition of the environment and the numbers of fish.

(Unit written by A. L. Dahl)
[Revision 26/02/85]

TEXT

FISHERIES MANAGEMENT

Fish and other animals from the sea provide an important source of protein for people in the Pacific. Fishing in the shallow coastal waters around the islands is an important occupation today as it has been for hundreds of years. The coral reefs, lagoons, seagrass beds, estuaries and mangroves are some of the most productive tropical island resources.

Because the animals in the sea are living things that grow and reproduce, they are a renewable resource; that is, they can continue to be used over and over again if they are taken care of. When a fish is caught or a shellfish collected, another can grow up to take its place. However, if too many fish are caught at once, it may not be possible for the few that are left to replace all those that were taken. This is called overfishing, and today it is happening in many places in the Pacific.

To avoid overfishing and other damage to fish resources, a fishery must be managed in accordance with certain ecological principles which are explained in the following sections. If local fishermen understand these principles, they can then decide on the kinds of management that will protect their fishery and keep it productive.

Hunting rather than farming

On the land, early peoples collected their food in the wild, digging up roots in the forest and collecting fruits wherever they found them. Later they learned that they could plant their food plants, and thus have more food than they could find in the wild. They thus went from hunting and gathering to agriculture. In the sea this change has hardly begun. In a few places men are learning to grow fish, shrimp, oysters and other sea animals, as well as seaweeds, as we do in farms on the land. This aquaculture is still at an early stage, and it requires a considerable investment and lot of scientific research to do it successfully.

Most fishing is still at the hunting stage. We collect for our use what is produced by the natural system, but we are not yet able to manage that natural system to produce even more of what we want. Because we have less control in fishing than in agriculture or livestock raising, we must learn to live within the limits of the natural productivity of the environment. At the most, we should try to avoid doing anything that might hurt that natural productivity and leave us with even less than would have otherwise been available. We therefore have to learn how much we can take from the natural system without hurting it. This is sometimes called the sustainable yield, and it may be only after a long period of trial and error that we can learn what it is. If we take too much, the system will produce less; if we take to little, some of the productivity has not been used; but finding the exact balance in the middle is not easy, particularly since natural productivity often varies. It is usually better to take a little less that we think is possible, rather than to take the risk of upsetting the whole system.

What fish need

Fish are just like any other animals in that they need food, shelter and good conditions for reproduction. A part of fisheries management is to ensure that these basic requirements are not changed for the fish you want to catch.

Each species of fish or other animal prefers certain kinds of food. Some fish may eat the tiny plants on the reef, or the corals, or little animals that swim in the water. Larger fish may well eat smaller fish. Some will feed in the daytime and others at night. It could be that food first made by plants on the reef will be eaten by a snail, which in turn may be eaten by a meat-eating snail, which is then eaten by a starfish, which is eaten by a shrimp, which is eaten by a small fish, which is in turn swallowed by a larger fish, which is then caught by a fisherman if it is not first eaten by a shark. In such a food chain, each animal depends on the one below it. If something happens to one of the animals, the others above it may go hungry, or have to eat some less desirable food. On a coral reef where there are many kinds of animals, the food chains (or food webs as they are sometimes called because they have many branches) may be very long and complicated.

Since the fish and other animals are both looking for something to eat and afraid of being eaten, it is important for them to have some place to hide. They also need shelter if they are to survive storm waves and to avoid being swept away from the island by currents. Environments like healthy coral reefs and mangroves provide good shelter for many kinds of animals, and this is one reason why they are so rich and productive. If mangroves are cut, or corals are smashed and broken, there will be less shelter and the fish populations will suffer accordingly.

No animal or plant lives forever. If a species is to survive and prosper, the generations must succeed each other. Each animal has its own time, place and conditions for reproduction when eggs are laid or the young are born. The tiny babies may not look like the parents, and may even go off and live in some other place before coming back as adults. Often the babies may be more sensitive and vulnerable than the adults, and some change that affects them will eventually affect the whole species. Since it is through reproduction that the fish caught by a fisherman are replaced, protecting and encouraging reproduction is very important to fisheries management.

Different species can have different strategies for reproduction. An animal may produce thousands or millions of eggs or young, but most of these will be swept out to sea, starve to death, be eaten up or find no place to grow up; only a very few will grow up to be adults. However, because there are so many, the chances of a few surviving are very good, and if something happens to one, another will almost certainly take its place. Other kinds of animals have found it better to produce only a few young, but to make them big and strong, or to protect them while they are small, so that their chances of growing up are much better.

The example of the giant clam will illustrate the problems of reproduction. Clams reproduce by squirting eggs and sperm into the water. If two clams are close enough to signal to each other through chemicals in the water, they may reproduce together and some eggs may be fertilized. The

baby clams may swim around for a while before settling down to the bottom and growing up, assuming they are not eaten in the meantime and can find a good place to live. Where fishermen take too many clams, the few that remain may be too far apart to reproduce successfully, and when those are gone there will be none left. In some places in the Pacific, local people protected an area with many clams, which could then reproduce and replace the clams taken all over the reef. It is even possible to move clams to be nearer each other and thus help them to reproduce. Otherwise overfishing of giant clams will drive them to extinction. It already has in some places.

Tropical ecosystems

The tropical ecosystems which produce most fish caught by island fishermen are very complicated, with many different kinds of species depending on each other and affecting each other. Because there are many different animals, there are many choices of food, many competitors, and many enemies, and thus many different ways the system can work.

Such ecosystems have generally existed for a very long time, so the animals and plants have had time to develop close relationships and many ways that they depend on each other. Big fish may depend on small cleaner fish to remove parasites on their skin and in their mouths that would make them sick. Clown fish depend on sea anemones to protect them from being eaten, and in turn they help the anemones to find food. Small shrimp and fish may share the same hole in the sand; the shrimp digs the hole, and the fish stands watch and signals if any danger is near. Giant clams are fed by tiny plants growing underneath their skin. Because of these relationships, a change on the reef or in the lagoon may have unexpected effects.

The reef is also divided up in many ways in time and space. Some animals may never meet because they come out at different times. Sunrise and sunset are times when there are many changes in what is out and what is resting. Some species gather together and travel as a group; others keep to one territory and chase away any intruders. Since space is hard to find, there may be several layers of plants and animals, with each one growing on the other.

All this means that any change in the system, like fishermen catching many of one kind of fish, can have effects all through the system, which may be vulnerable in ways that do not seem evident at first. If too much of any one kind is taken away, a balance may be upset, and it may be replaced by something else which may be less useful or desirable. If too few of the species are left, it may simply not be able to re-establish itself in the face of competition from other species (or from man). On certain reefs where the corals were killed, their place was taken by soft corals which provide less food and shelter. One kind of giant clam was fished to extinction in Tonga, and sea turtles have all but disappeared from many areas.

Fisheries management

Successful fisheries management in tropical coastal waters depends on a detailed local knowledge of the kinds of fish and their behavior. On islands where people have fished for hundreds of years, this knowledge has accumulated and has been used to establish various traditional fishing rules and practices. It is often when this knowledge is forgotten or ignored that the fish resources are damaged.

It is essential that both the methods used for fishing and the other human activities along the shore must not hurt the ability of the coastal waters to produce food and shelter for the fish. If there is less food, or fewer places for fish to hide, there will be fewer fish.

Some fishing methods are very destructive, but they are still used because they are easy or do not require much knowledge and skill. Breaking up the coral with hammers and bars to get the fish hiding inside can ruin shallow reef areas. Using dynamite or other explosives for fishing is quick and easy, but it kills everything and reduces the corals to a heap of rubble. A dynamited reef can only be fished once; afterwards there is not much left worth catching. Too many fishermen have also been killed or injured with their own explosives. The use of poisons such as Derris root can also kill much more than the fisherman needs. Where such poisons were known traditionally, they were generally used in moderation or where no alternative was available. Modern household chemicals such as chlorine bleach also kill everything they touch, and thus kill not only the fish, but their food and the baby fish of the next generation. An area that has been poisoned will recover very slowly. The more recent use of pesticides and other poisonous chemicals for fishing can be as dangerous for the fisherman (and his family) as for the fish, as these poisons can stay in the fish and make anyone who eats them sick.

Many other things that people do can also hurt coastal fisheries. Dredging coral, filling, or building structures along the shore can change or destroy the natural areas where fish live and feed. If the land is cleared and heavy rains wash the soil down into the water, the muddy water will keep light from reaching the plants on the bottom so they can no longer make food, and as the sediment settles out it can smother and bury the corals and other animals. Pollution from cities or villages can upset the balance of life in the coastal waters, and the fish and shellfish may take up all sorts of disease germs which can make anyone who eats them sick. Industries also can pollute coastal waters with chemicals, sediment or heat that will hurt local fisheries. Even dropping anchor frequently on a coral reef can break up the corals and reduce the reef productivity.

An essential part of fisheries management is controlling how much fishing is allowed in each area and for each species over each period of time, so that the catch is not more than the area or species can replace. This means knowing how quickly a species can replace itself, over what area the replacement takes place, and how many adult fish are needed to keep up the level of reproduction. It may also be necessary to know what size fish are the best breeders (or is one size male while another is female?), and where breeding takes place. Some fish may have a particular time or place for breeding when they are particularly vulnerable, and where any fishing will have a disastrous effect on their reproduction.

This kind of knowledge or an approximation of it has often been accumulated by traditional fishermen over generations, and is reflected in their fisheries management. In the absence of scientific studies, such traditional knowledge may be the best guide to fisheries management.

It is a common error for an outsider to come in and be struck by the large number of fish in an area. His first reaction is often that those fish are a resource going to waste. However, it is not the number of fish but the rate at which they can replace themselves that is the real resource. Catching all the fish with some new technique may simply mean that there will be no fish left.

A certain number of fish can usually be caught without affecting the population. When more than that is taken, the number of fish may drop very quickly. The wise fisherman learns to recognize the signs of overfishing and knows when to stop catching that species so that it can recover. There may also be times when a fish population may already be under stress from some natural cause (bad weather, shortage of food, etc.) making it even more vulnerable to overfishing.

The evidence suggests that most subsistence fisheries in the Pacific Islands probably already use their shallow coastal fish resources at close to their biggest sustainable catch. There is thus little possibility of fisheries "development" in such areas without going offshore or into deeper waters. It is difficult to find an example of a commercial tropical shallow water fishery that has not led to overfishing and a decline in local subsistence resources. People for whom their local catch is an important food resource would do well to manage their coastal fishery to maintain their food supply, and not try to develop it as a source of cash income.

Management techniques

The ways in which a coastal fishery can be managed will depend on the laws and customs of each area. The measures taken to manage fishing must have some possibility of being enforced, either by the traditional authorities or the government. Some decisions taken within a community can be enforced by community pressure on its members. The fear of disapproval or condemnation by one's friends and neighbors can be a powerful deterrent within a community, but is less effective for outsiders. In any case, a regulation that is understood and accepted by the members of a community has a much better chance of working than one that is simply imposed by the authorities.

LIMITED ACCESS

The laws of most developed countries do not recognize private or community ownership in coastal waters; the seashore and everything below high water mark usually belong to the government and are open to the public. When everyone has a right to go fishing, it is hard to control the amount of fishing. Each fisherman tries to catch as much as he can, because if he does not catch all the fish, someone else will. It is not possible to decide to leave some for the next time. The traditional way in many Pacific Islands was

different. Families or villages owned parts of the reef and lagoon, and anyone wanting to fish there had to have permission. This ownership of the coastal waters or of the right to fish there limited the number of fishermen and gave them the responsibility to take care of the resource. The fishermen knew their area well, and could decide to protect certain fish or fishing grounds if necessary. To the extent that local laws permit, this can be one of the best ways to manage a fishery.

CLOSED SEASONS

Many fish have a reproductive season when they produce the baby fish that replace those that have died or been caught. It may be easier to catch them when they are reproducing, but catching or disturbing them at that time will prevent them from replacing themselves. Protecting the ability of the fish to produce many babies is one important way of ensuring there will always be enough fish to catch. This can be done by establishing a closed season when no fishing for that kind of fish is allowed during the time it is reproducing. This was often done in traditional fisheries management through rules or taboos which allowed fishing for some species only at certain times of the year.

A fish population may also be seriously reduced, either by natural causes such as a cyclone or unusual conditions, or by overfishing. Prohibiting fishing for that species for a period of time will allow it to recover to its former numbers.

PROTECTED AREAS

It is also possible to protect certain places that are important for the fish. Some kinds of fish have a special place, perhaps in a lagoon or mangrove swamp, where they go to reproduce or lay their eggs, or where te young fish live while they are growing up. Protecting these places from fishing or from being damaged by development will help to protect the fishing all over the island. A part of the lagoon or reef that is protected and where no fishing is allowed can serve fisheries management in another way. Fish that live in the protected area will grow large and will produce many babies. The young fish will move out of the protected area to find a place to live, and will thus help to keep the rest of the island stocked with fish where fishermen can catch them. Making a protected area can thus help to make the fishing better elsewhere.

Protected areas are nothing new. In former times some areas were protected because they were too hard to reach in canoes without motors. Other areas were sacred or taboo, and no fishing was allowed. Today, many countries are creating marine parks or reserves both for fisheries management and to protect places tourists like to visit.

Some countries have created rotating reserves where fishing on the reef is very heavy. A part of the reef is closed to fishing for several years to allow the fish populations to recover. Then the first area is opened again and a second is closed to let it "rest" and regenerate. A few years later it is the turn of a third area to be closed, and then the process starts over again.

LIMITING FISHING TECHNIQUES

Another way to control fishing in areas where overfishing is a problem is to limit or prohibit certain fishing techniques. Many areas have banned spearguns because with them it is easy to kill all the big predatory fish on the reef such as snappers, groupers and emperors, to the point that there are hardly any left to reproduce and replace those that are taken. Prohibiting the taking of lobsters or crayfish with scuba diving gear protects those animals that live in deeper water. Nets with a small mesh size will catch not only the large fish, but also many small fish of little interest which should be left to grow bigger. By allowing only larger mesh nets, it is possible to permit the catch of the larger fish while letting the small ones go free. Prohibiting all fishing with explosives and poisons is important to protect the whole fishery; such destructive fishing is already illegal in most countries.

SIZE OR CATCH LIMITS

Another common fisheries management approach is to limit the number or size of fish or other animals that can be caught. Catch limits which allow a fisherman to catch or to have in his possession only a certain number of fish each day help to keep some fishermen from taking more than their share and to keep the total catch within safe limits. Size limits make it illegal to take fish or shellfish of less than a certain size, usually related to the size at which the fish start breeding. Occasionally the largest fish or animals may also be protected, as with the crocodiles in Papua New Guinea, since they may be the best breeders. Size limits are generally designed to ensure that there are enough fish reproducing to maintain the population, and to give the young fish a chance to grow up. It can also be made illegal to catch breeding females or those carrying eggs or young, as is often done with lobsters and crayfish.

Such fisheries management measures were common in the traditional island cultures, and were often enforced through traditional beliefs and taboos. Today it is more often the government that takes such measures through laws and regulations. However, there is nothing to prevent a tribe or village that has control of its coastal waters from managing its own fishery. Any management measures have more chance of working if they are understood and appreciated by the local fishermen and if they are supported by group pressure as well as punishment. It is hard, particularly in the islands, to go against the views of one's family and friends and to risk criticism in the local community. Such pressure is the best way to stop those who fish with dynamite or poisons because they are quick and easy ways to get a large catch (generally to share with family and friends). If everyone realizes that good fisheries management is in the interest of the whole community, and everyone works to make it effective, then the chances are good that the community will continue to have a good supply of fish long into the future.

QUESTIONS .

Is fishing more like farming or like hunting? Why?

What do fish need in order to live?

Why is fish reproduction important?

What are different ways that fish or shellfish ensure that those that are caught or lost are replaced?

Why are coral reefs and other tropical ecosystems so complicated?

What can happen if fishermen catch almost all of one kind of fish?

Do you know of examples of over-fishing in your own area?

Is protecting the fish enough, or are there other things to protect in coastal waters to keep the fishery productive?

Why is breaking coral or fishing with dynamite or poison bad for a reef?

What are some of the techniques that can be used to manage a fishery?

Are traditional fisheries management measures still observed in your area?

What do you think needs to be done so that there will always be enough fish to catch?

South Pacific Regional Environment Programme

Training Unit C7

CONSERVATION OF NATURE

USE OF THIS UNIT

An important aspect of environmental management is the conservation of natural areas and natural resources to ensure the future survival of the native fauna and flora. This unit gives a simple explanation of conservation and the reasons for its importance. Each sub-topic can be presented and then discussed by the group, adding local examples wherever possible.

The treatment of the topic can be expanded with supplementary materials and audio-visual programmes as appropriate.

AUDIO-VISUAL SUPPORTS

The IUCN/WWF slide-tape programme Why Conserve Wildlife? can give a world perspective on the importance of conservation. A short slide programme on National Parks and Reserves in the South Pacific is available with this unit.

EXERCISES

If there are parks or reserves in your country, a field trip to visit them would be appropriate.

There are often local people interested in native birds or plants who could speak to the group, or even take them on a field trip to some natural area.

If time permits, participants could prepare short projects collecting information on local species or natural areas in need of protection.

SUPPLEMENTARY MATERIALS

The World Conservation Strategy prepared by the International Union for Conservation of Nature and Natural Resources (IUCN) can be used to expand the global aspect of this unit. The first seven sections, including the introduction, the objectives of conservation and requirements for their achievement, are particularly pertinent. [Available from IUCN, 1196 Gland, Switzerland].

The Regional Ecosystems Survey of the South Pacific Area by Arthur L. Dahl (South Pacific Commission Technical Paper No. 179, 1980) gives an outline of conservation needs and accomplishments for each part of the Pacific Islands.

(Unit written by A. L. Dahl)
[Revision 28/11/84]

TEXT

CONSERVATION OF NATURE

What is Conservation?

Conservation means protecting something from change or destruction while permitting its wise use. It thus involves managing our use of natural resources so that we can benefit from them now without damaging the possible benefits they can provide in the future. In the Pacific, conservation of nature is protecting the forests, animals, birds, plants, fishes and marine life so that they will always be here for future generations to use and enjoy.

There are many reasons for conserving our natural heritage.

-- Human survival and development depend on natural processes that maintain the system within which we live, for example by making good soil, purifying water or recycling nutrients.

-- The native plants and animals of an island are genetic resources, many of which are found no where else on the planet. They have had traditional uses, and they may prove to be very useful in the future.

-- Biological resources are basically renewable; that is, if cared for, they can continue to produce indefinitely. Since future civilization will have to depend more and more on renewable resources as our oil, coal and minerals run out, it is essential that we conserve those resources so that our society can continue to grow and develop.

-- Natural areas are of great scientific interest as places where the principles of ecology and natural history can be studied.

-- The forests in the islands protect important watersheds; destroy them and we may not have enough water for development, or even to live.

-- It is nature that makes our islands beautiful places to live, so we must try to protect that beauty for ourselves and for its importance to tourism.

-- Conservation is important for education; students can learn more easily about biology, ecology, geography and natural history if they can see examples around them.

-- Traditional life and culture in the islands depend on the land and sea, forests and reefs, so conservation also means protecting the roots of our culture.

Conservation and Development

Conservation is a part of good development. Both conservation and development try to give people the best possible life that their resources permit. Sometimes a particular development may overlook some long-term costs associated with it, such as a land-clearing project that damages a water supply, or a new factory that pollutes a lagoon and kills fish used by local fishermen. A conservationist would ask if the long-term loss of the water supply or fishery might not be worth more than the short-term benefit from the development, or if the development could not be modified or relocated to reduce the damage caused. Environmentally-sound development is development that continues to produce benefits for the people indefinitely into the future. A conservation approach can thus help to choose wise development that does not steal from the future for the benefit of the present.

Conservation of Species

The Pacific Islands are particularly rich in kinds of plants and animals, called endemic species, that are found nowhere else in the world. This is because islands are isolated, and were often populated long ago or by chance; the plants and animals that succeeded in reaching them have often changed and adapted to suit local conditions. These unique species are an important genetic resource for the whole world, and may well prove to be very useful in the future.

Unfortunately the populations of island species are often small, and they can easily die out or become extinct if the place where they live is changed or developed, if they are hunted or harvested too much, or if an introduced plant or animal kills them or crowds them out. Most extinctions in the last hundred years have been of island species, and many others are endangered, that is they could easily disappear if care is not taken.

Protecting this genetic heritage is a great responsibility for Pacific people,and one that is ot easy when different needs conflict on a small island. In the Pacific, there are many more endangered species in relation to the size of the population than anywhere else in the world. Often these species were important in legends or in traditional life. If they are lost they can never be brought back, and both the ties with the past and the hopes for the future will suffer.

Protected Areas for Conservation

Every country has some areas that need to be protected. These may be natural areas of forest or reef where rare or endangered species live, areas where the natural life is particularly rich or productive, typical examples of a local natural ecosystem, sites of historical interest or natural beauty important for tourism, areas essential to life on the island (such as by catching water or protecting against natural disasters), and sites of critical importance to the productivity of resources necessary for development (fish breeding areas, genetic resources, etc.).

While some laws may protect individual species against hunting or collecting, the best protection is to set aside the places where they live. Therefore most countries, including many in the Pacific, have created national parks and reserves to keep these important areas safe for present and future generations. National Parks (or territorial or provincial parks in some places) are generally large areas open to the public for recreation and the appreciation of their natural features. Reserves are usually smaller or narrower in their purposes; they may be nature reserves, historical reserves, marine reserves, recreation reserves, hunting or forest reserves. Protected areas can serve several purposes, like protecting a water supply and providing a safe place for native birds, or encouraging tourism while protecting a historical or cultural site.

While it is usually the government that sets aside an area as a national park or reserve, it is up to all the people to understand the importance of protecting these areas and to respect the rules for their use. Pacific Island governments do not have the resources to police these areas without public support. There have been sad cases in the Pacific where parks or reserves have not been respected by the people and their natural features have been destroyed. It is future generations who suffer from such a loss.

Protected areas have many uses apart from safeguarding nature. They are places for educating the public about the importance of nature to our daily life. School children can visit them to learn about their natural and cultural heritage. Scientists can use them for research on the natural processes that have made the islands what they are today, the knowledge of which is essential if we are to manage them in the future. They can be an important tourist attraction with benefits for the local economy. Creating parks and reserves is therefore a kind of development project that has its place with others in a well-balanced development programme.

There are now about a hundred parks and reserves in the South Pacific region, including National Parks such as Varirata in Papua New Guinea and O Le Pupu-Pu'e in Western Samoa, nature reserves like Montagne des Sources in New Caledonia, Tomaniivi in Fiji, Maug in the Northern Marianas, Rose Atoll in American Samoa, and Taiaro in French Polynesia, and marine reserves such as Palolo Deep in Western Samoa, Yves Merlet in New Caledonia and Monuafe Island in Tonga. These protected areas include important examples of undisturbed natural environments, but they are still not enough to protect the great natural diversity of the Pacific Islands.

Individual Conservation Actions

Since conservation means keeping our resources productive for the future, there are things that everyone can do to contribute to conservation.

It will be very difficult for governments to set aside enough examples of different kinds of native forest, reef, and other natural or beautiful areas as national parks and nature reserves to meet the needs for conservation, education, scientific research and recreation. Local tribal groups and land owners can organize to protect their own resources, as has been done with the wildlife management areas in Papua New Guinea. Traditional land owners can also preserve parts of their land which have natural or cultural

importance by not developing them in ways that would damage their features of interest; such "family reserves" could play an important role in island conservation.

Farmers and land owners can plan the use of their land to protect the soil for gardens and to maintain their supplies of food, firewood, forest products and water. For instance, trees can be left along stream banks, in upper watersheds and on steep slopes. Trees are important, so anyone who cuts one down can plant another.

Fishermen can avoid using destructive methods like dynamite, poisons, coral breaking or small-mesh nets, and can try not to overfish any one area. They can even stop fishing for a time in some areas to allow the fish populations to recover, just as was often done under the old taboo system.

Traditional Conservation

People living traditional ways of life in the Pacific paid close attention to the natural environment and often managed it wisely. They knew when to use resources in moderation, or when a wrong practice would damage a resource for later use. Taboo areas in the forest or on the reef were conservation areas just like parks or reserves. Today much of the knowledge that old people have about the forests, medicinal plants, fishes, reef life, and places to protect is being forgotten. Young people are away at school, or not interested. Since there are many wise things in the traditional ways that can help in managing island resources today, conservation should include preserving such knowledge so that it can be applied to modern problems.

QUESTIONS

Why is conservation important in your country?

Why is conservation important to the whole world?

Is conservation against development?

Why can a national park be considered a development project?

What can happen if development goes ahead without conservation?

What should be done for conservation of nature in your country or island?

What can you do in your own area to help conservation?

What are some traditional types of conservation on your island?

ANNEX

National Parks and Reserves in the South Pacific

SLIDE PROGRAMME

This short slide programme shows some of the national parks and reserves that have been created by island countries in the South Pacific to protect areas of scientific interest, natural beauty, or importance for resource management.

	SLIDE	DESCRIPTION
1.	Title	National parks and reserves are places set aside to protect features of natural or historic interest. A park is open to the public for uses that do not disturb its natural features, like recreation or education. A reserve is smaller or has a special purpose like protecting an endangered species or a tourist site.
2.	Park facilities	There are only a few national parks in the region, including 1 in Western Samoa, 2 in New Caledonia and a few in Papua New Guinea. This is a view of the visitor facilities in Varirata National Park near Port Moresby, Papua New Guinea.
3.	Palolo Deep from air	More countries have established marine reserves, including American Samoa, New Caledonia, Papua New Guinea, Tonga, Western Samoa and Vanuatu. This is an aerial view of the Palolo Deep Marine Reserve near Apia, Western Samoa.
4.	Reef flat	Palolo Deep is a depression in the reef flat that is often visited by tourists.
5.	Corals	It contains many fish and large corals. Making it a reserve protects its beauty as a tourist resource.
6.	Ha'atafa Beach	Tonga has created 5 marine reserves in the waters off Tongatapu. This is the Ha'atafa Beach Reserve protecting a beach and reef often visited by tourists.
7.	Corals in reserve	The Tongan reserves protect areas of rich coral and reef life that should become centres of reproduction helping to maintain the fish populations on surrounding reefs where fishing is allowed.

8.	Corals in reserve	Such reserves are especially important in areas where there are many fishermen and problems of overfishing. However enforcing the prohibition on fishing in reserves is not always easy. The people must be educated to see the importance of the reserve.
9.	Sign, Merlet Reserve	In New Caledonia, the Yves Merlet Reserve protects a 16,000 hectare section of the barrier reef. There are also reserves around islets often visited by tourists, and a rotating reserve protecting the most visited parts of the barrier reef from overfishing.
10.	Rose Atoll	Some countries have set aside whole uninhabited islands or atolls as reserves. This is the Rose Atoll National Wildlife Refuge in American Samoa. There are other island reserves in Kiribati, Cook Islands, French Polynesia, and the Northern Mariana Islands.
11.	Sand island	Other types of reserves are needed to protect the breeding areas of species that migrate around the region, such as turtles and sea birds. This is an islet on Tetiaroa in French Polynesia where seabirds breed.
12.	Nesting bird	Seabirds, like many animals, are vulnerable to disturbance while nesting, so this protection is important if their populations are to be maintained.
13.	Archaeological site	Making a reserve may be the best way to protect historic and archaeological sites of great cultural importance.
14.	Crocodile farm	Other conservation measures besides reserves are also needed to protect wildlife. In Papua New Guinea, crocodile farms like this one are encouraged to provide village income. The people then protect the wild crocodiles which provide the babies for their farms.
15.	Crater lake	Many more parks and reserves are still needed to protect the important natural areas, historic places and habitats of rare species in the islands, like this mountain forest and crater lake on Savaii, Western Samoa.

South Pacific Regional Environment Programme

Training Unit C8

CORAL REEFS

USE OF THIS UNIT

This unit gives a basic explanation of what a coral reef is and how it works, as well as some of the problems associated with coral reef management. The text can be studied by or presented to the group, with the aid of the coral reef poster. Audio-visual materials and/or field trips are essential to give visual and practical experience with coral reef areas.

AUDIO-VISUAL SUPPORTS

The slide programme accompanying this unit covers material corresponding to the text. There are also a number of films available illustrating coral reefs. Where projection facilities are unavailable, there are many books about reefs with excellent color pictures which can be used to illustrate the unit.

EXERCISES

The best possible exercise is a field trip to a coral reef, which should not be too difficult to arrange in most Pacific Island areas. A relatively protected reef or a patch reef in a lagoon are the best sites for such an introductory field trip.

If possible the trainees should be provided with masks or goggles, preferably with snorkels, to make it possible to see the reef life under water. Sturdy shoes (tennis shoes or equivalent) are necessary if a reef flat must be crossed on foot. Ideally the group should be accompanied by someone who can explain features of coral reef ecology in the field and point out interesting features.

SUPPLEMENTARY MATERIALS

Related topics are treated in the units on lagoons, mangroves, fisheries and monitoring coral reefs.

The UNESCO "Coral Reef Management Handbook" can be obtained from: UNESCO Regional Office for Science & Technology for SE Asia, Tromol Post 273/JKT, Halan Thamrin 14, Jakarta, Indonesia.

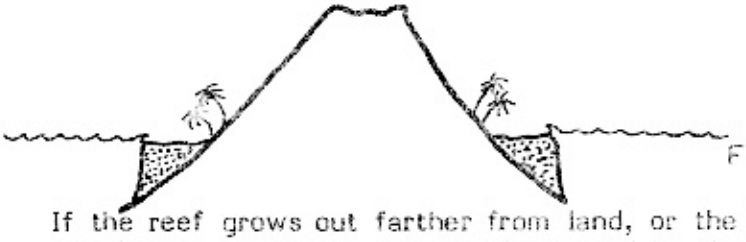
(Unit written by A. L. Dahl)
[Revised 06/03/85]

TEXT

CORAL REEFS

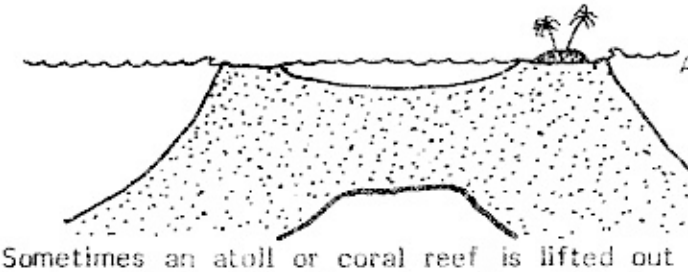
What are coral reefs?

Coral reefs are built near the surface in tropical seas by the accumulated skeletons of tiny animals (mostly corals) and plants (coralline algae). Wherever sunlight reaches a suitable bottom, such as on the side of a volcano that has reached the surface, corals will start to grow. Over many years they build a reef that fringes the shoreline (a fringing reef).

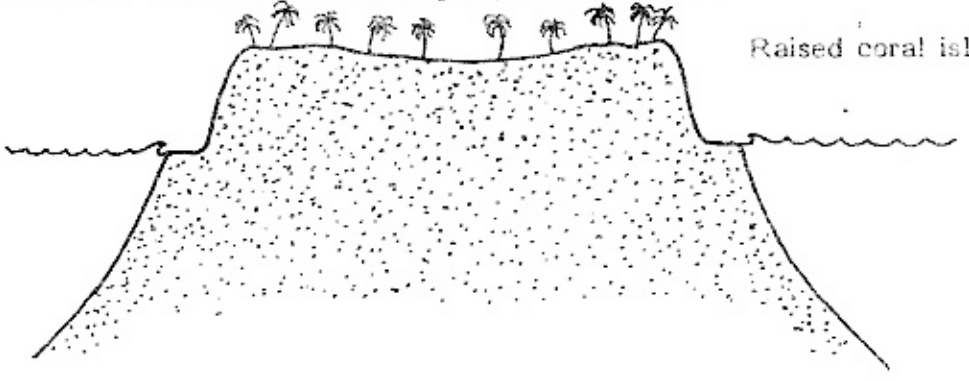


If the reef grows out farther from land, or the land sinks and the reef keeps growing, then a barrier reef is formed with a lagoon behind it.

If a volcanic island that started with a fringing reef sinks completely beneath the surface, while the reef keeps growing, then only a ring of reef around a lagoon is left behind, making an atoll.



Sometimes an atoll or coral reef is lifted out of the water, making a flat raised coral island like Tongatapu, Niue, Makatea or Nauru.



Why are coral reefs important?

Coral reefs are a very productive type of ecosystem with many kinds of plants and animals crowded together. Even though the clear waters of the tropical ocean are very poor in life, coral reefs are able to collect and recycle the materials they need to grow. They are thus to the tropical oceans as an oasis is to a desert. This makes them of great scientific interest.

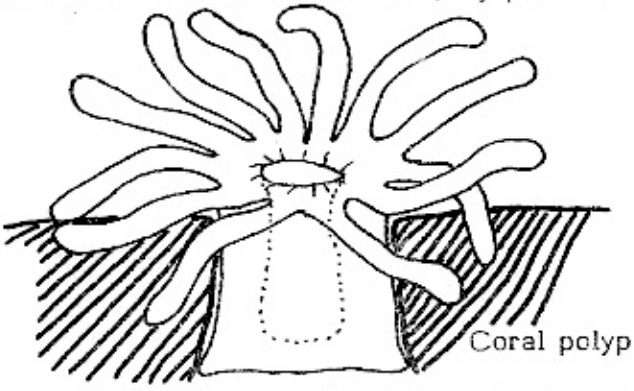
The reefs are important to the life of many island people. The fish, shellfish and other reef animals are an important source of food, providing essential protein for island diets. Many different kinds of fishing and food collecting are possible in reef areas, producing very high catches, although these can be reduced by overfishing if care is not taken.

As coral reefs grow, they add to the size of islands, making sand, rubble and rock that build the island. They also take the force of the waves, protecting the land behind. They thus help to protect the island from storms and keep it from washing away. Many Pacific Islands are made entirely of coral reefs, and most others have been added to or protected by them. The relatively calm and productive lagoons of many islands are also created by the surrounding reefs. Since reefs are built by living plants and animals, anything that damages the life on the reef also slows or stops its growth, threatening the long-term future of the island.

It is therefore important to know something about what makes up a coral reef and how it works.

Corals

Corals are made up of tiny animals living in colonies of many thousands that grow together to produce the coral skeleton. Each coral animal or polyp has a central mouth and stomach surrounded by a ring of arms or tentacles with which it catches its food (tiny plankton animals) floating in the water.

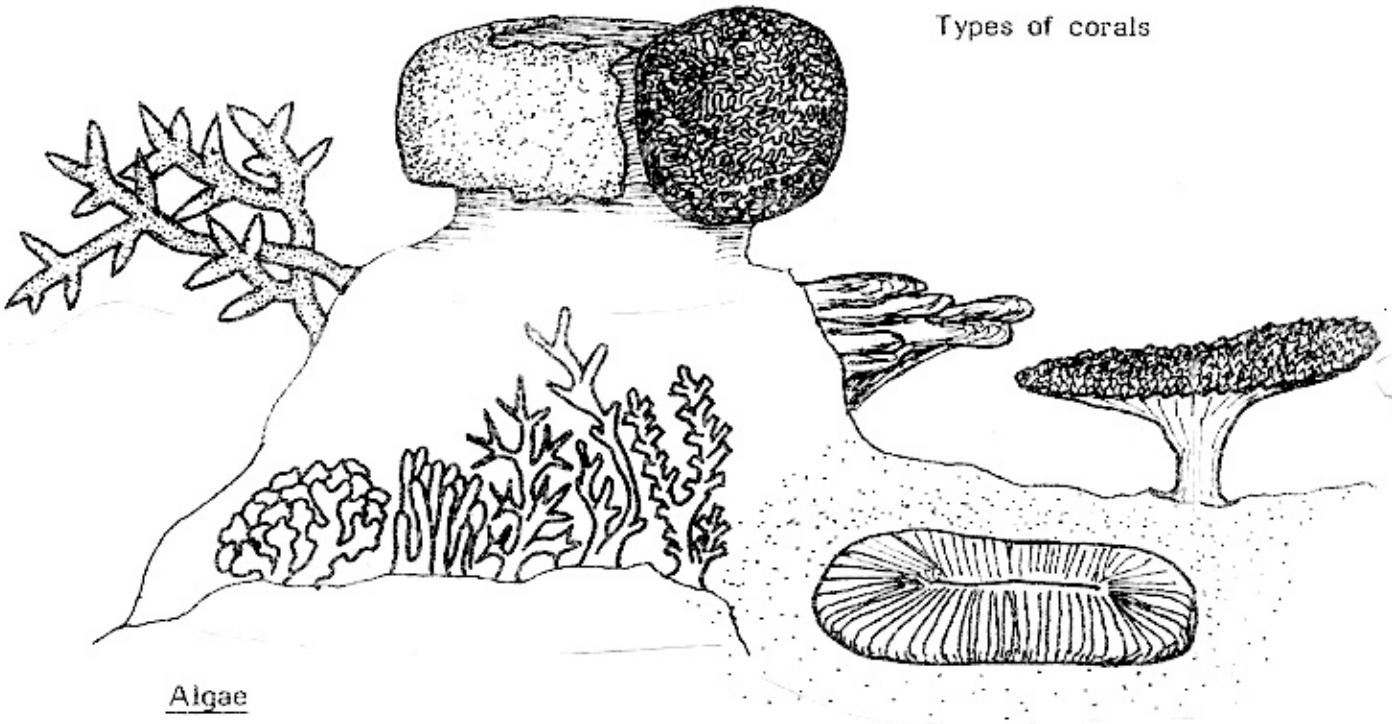


Corals also get food from single-celled plants called symbiotic algae that live inside them and make food from sunlight just like other plants.

Reef-building corals only live in shallow water where there is enough light, and they will die if the water gets too dirty for light to reach them. Corals grow very slowly, so if they are broken or killed by pollution or dynamiting for fish, the reef will take many years to recover.

Many corals have branches and look like plants. Indeed, they are to the reef what trees are to the forest. Just as the forest birds disappear when the trees are cut, so do most reef fish go away when the corals are broken or killed.

Types of corals

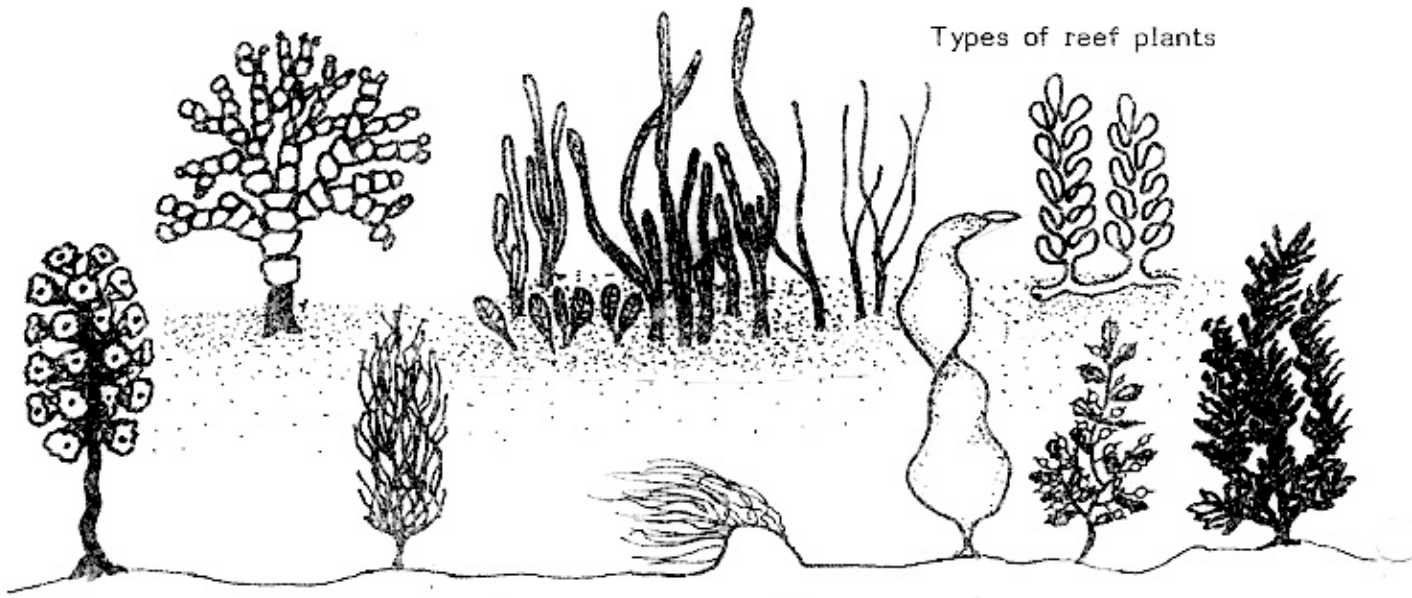


Algae

Algae are simple plants that make most of the food for the coral reef. Some of the larger seaweeds, often called limu in the islands, are also eaten by people.

Many algae have stony skeletons like the corals, and they may be as important as corals in building the reef and in producing the white sand of coral beaches. The pink coralline algae help to cement the coral skeletons together to make a strong reef, and often form an algal ridge just where the waves break, thus protecting the more fragile corals behind.

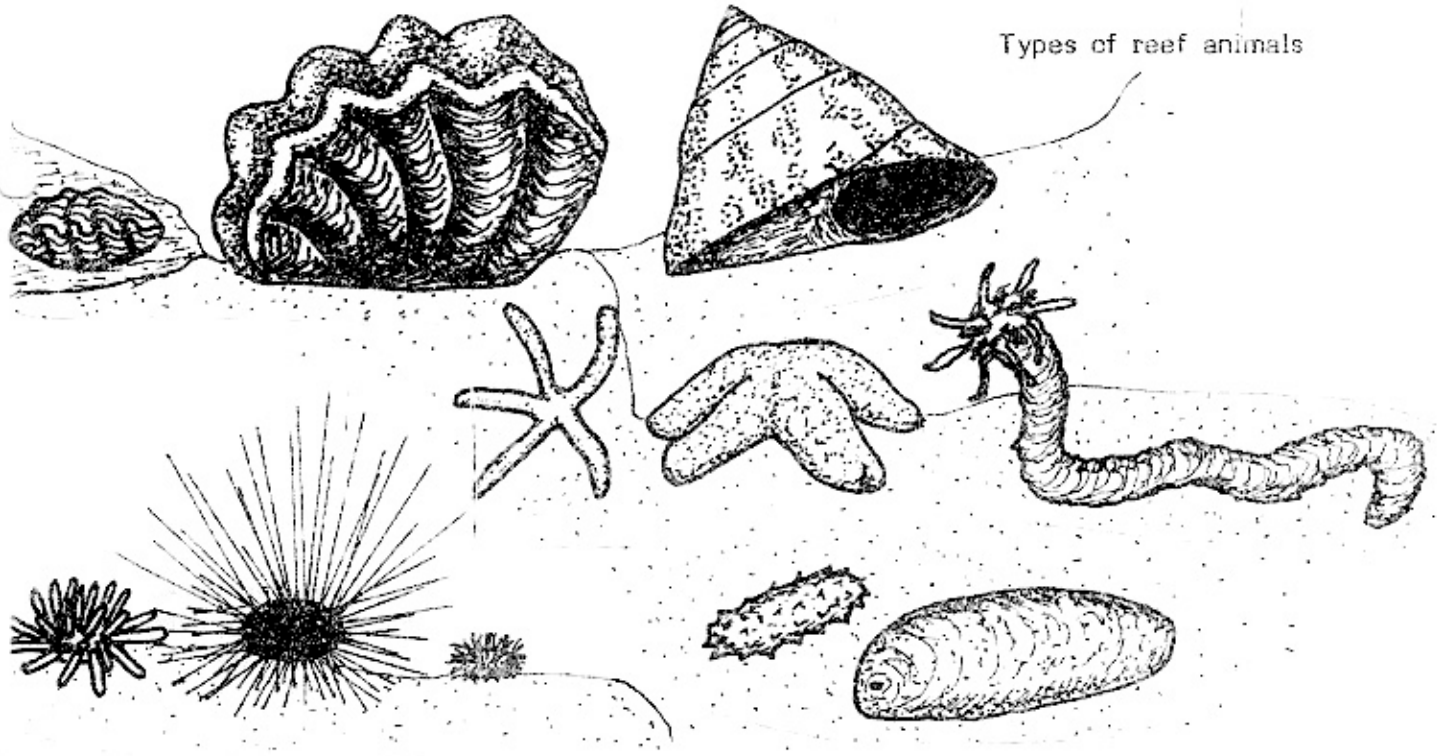
Types of reef plants



Animals

There are many kinds of animals and fish that live on the reef and are important to reef ecology. Some eat mostly algae and other plants. Others eat corals or other animals. Still others eat dead material (detritus) and thus help to keep the reef clean.

Reef animals such as octopus, shellfish and fish are often collected at low tide, or at night with torches or lamps, and provide protein for island diets. Reef shells are used for handicrafts and are popular with collectors, but if too many are taken, this can upset the balance of reef life.



Types of reef animals

Coral reef ecology

The coral reef ecosystem is both very old and highly efficient, with many hundreds of kinds of fish, plants and marine animals crowded together in complex communities rather like modern cities. Reef life is efficient at recycling food and nutrients within the system, and each species has a special role to play, just like the many occupations of people living in a city.

The reef ecosystem requires a stable environment without much change in water quality or temperature; if that environment is disturbed, the reef may die or may take many years to recover.

A coral reef is built up over thousands of years by the skeletons of generations of corals and algae, yet man can destroy the living system of the reef in a few moments. Evidence from many parts of the Pacific suggests that many coral reefs are declining steadily in quality and productivity. Damaged and degraded reefs are now the rule around centres of population. If this trend continues, an important resource for many islands will be lost.

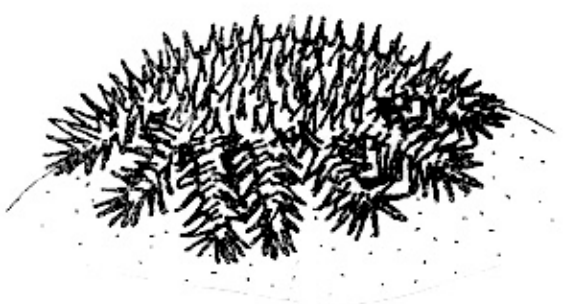
What is destroying coral reefs?

Life on a coral reef is a delicate balance of many factors, and as with any living community, it may go through natural changes. These may be random changes, cycles of growth and destruction that repeat over time, or progressive evolutionary developments, say from one type of reef or structure to another. Human activities can interfere in many ways with this balance.

Some problems come from the use or misuse of reef resources. Overfishing or heavy spear-fishing (which selectively removes the large predatory fish) may lower fish populations, particularly of the most useful species. Collecting of shells, corals or aquarium fish can also upset population balances. Destructive fishing techniques like breaking coral, or using dynamite and poisons destroy the structure of the reef and can kill everything including the baby fish and the food on which the fish depend. Too much use of such techniques can turn a rich productive reef into a desert.

Many kinds of pollution can also damage or destroy a coral reef. The most important in the region is probably sediment and muddy water from soil erosion on land. As land is cleared the soil washes away and generally ends up in the lagoon or on the reef. The muddy water keeps light from reaching the plants on the bottom, and the sediment smothers the corals and other animals. Many cities and villages also empty their waste water and sewage onto the reef, changing the balance of nutrients and making the seafood unsafe to eat. Runoff from agricultural land may include pesticides and fertilizers. Ports, industries and power stations may cause serious local pollution from oil, industrial wastes, heat or heavy metals.

The reef can also be disturbed or damaged directly by dredging or construction. Even recreational activities like diving and boating can cause broken coral; in areas of heavy use, much of the coral can be broken over time. The reef can also be disturbed biologically by the introduction of species not previously found there, or by population explosions such as the coral-eating "crown-of-thorns" starfish, Acanthaster, which may have both natural and human causes.



Crown-of-thorns starfish

Use and Management of Coral Reefs

Traditional fisheries in the Pacific made good use of coral reef resources, based on detailed knowledge of many reef fish and other animals. In many cases the amount of fishing was controlled, often by taboos and other practices, and some of each kind of fish was taken at different times so that the balance of reef life was maintained. The limitations of traditional fishing technologies and sailing canoes also meant that many fish escaped and that more remote regions were rarely fished.

Modern technologies like nets, boats and diving equipment have made fishing easier today, but they have not made it possible for more fish to live on the reef, and after an initial period of success, catches have often declined with overfishing, sometimes even to less than traditional levels. Many subsistence fisheries seem to have approached the sustainable catch on local reefs, and attempts to develop large-scale commercial or export fisheries in coral reef areas have generally failed.

The increasing damage to coral reefs by development, pollution and destructive fishing has also reduced the amount of fish a reef can produce, while the demand for fish has generally increased. The risk of ciguatera fish poisoning has also made many fish resources unusable.

Coral reefs are difficult to manage because they cannot be fenced in or protected like land areas. They are influenced both by the open ocean and often by the adjacent land, as well as tides and currents that can bring damaging factors from far away.

Often traditional management rules can serve as guidelines for modern management practices in reef fisheries. When new techniques are introduced, their use must be kept within the limits of the resource. The prohibitions on destructive techniques like dynamiting must be strictly enforced, especially by the fishermen themselves.

Where reefs are subject to damage from the land, such as erosion, fresh-water run-off or pollution, controlling activities on the land is the only solution.

The creation of coral reef reserves or other protected areas can provide reservoirs where healthy populations can multiply and spread to replace fish caught in adjacent areas. The breeding sites and migration routes for important fish species may also need to be protected.

Many coral reefs in the Pacific have already been damaged by man's activities. Only careful management can prevent further damage to reef resources and maintain the productivity of coral reefs on into the future.

What can you do?

If you are a user of coral reef resources, you must realize that the reef is a living community and learn to respect its limits.

Fishermen should just catch what they need, being sure to leave some fish behind to replace what they have taken. Avoid catching animals while they are reproducing; wait at least until they have left a new generation behind. If the catch size gets smaller and smaller, fish for something else and let that area or species recover.

Villages or family groups with traditional fishing grounds can decide together on the rules needed to manage their reef fishery wisely. Such rules might include a ban or limit on spearguns, requiring nets with a mesh size large enough to let little fish escape, and the prohibition of damaging fishing techniques. Access to certain areas can also be limited, and reserves or closed seasons established to protect the breeding areas and times of vulnerable species.

Even if you do not live on the coast, your actions may be damaging coral reefs. Cutting too much forest, clearing the land without erosion controls so that it washes away in heavy rains, overuse or spillage of fertilizers or pesticides, pollution of water by village or city wastes, are ways in which everyone living on an island may contribute to hurting coral reefs and other coastal resources. Only when everyone observes the principles of good environmental management can resources such as coral reefs be preserved.

QUESTIONS

What do coral reefs do for Pacific Islands?

How are coral reefs made?

What do the coral reefs look like in your area?

Are there many fish on your reefs?

If not, what has happened to them?

What was fishing like in your grandfather's time?

Are any traditional fishing practices or controls still used today?

Have reefs in your area been damaged?

If so, what has damaged them?

What can be done to manage your reefs more wisely?

ANNEX

CORAL REEFS

SLIDE PROGRAMME

This slide programme describes coral reefs and illustrates some of the principles of coral reef ecology, as well as touching briefly on some threats to coral reefs. It can be used to introduce the coral reef environment, or as background, together with the text of unit C8, for a discussion of coral reef management. The illustrations have been taken from both Pacific and Caribbean coral reefs. (All photographs by A. L. Dahl).

	SLIDE	NARRATION
1.	Title	What are coral reefs?
2.	Coral reef (Palau)	Coral reefs are ridges or structures of coral limestone built in the warm waters of shallow tropical seas
3.	Corals (Samoa)	by the accumulated skeletons of corals and algae piled up slowly and cemented together over many thousands of years.
4.	Volcanic island & reef	Wherever in the tropical oceans there is a hard bottom near the surface, as here on the volcanic island of Tahiti, a coral reef will start to grow out from the shore, making a fringing reef.
5.	Fringing reef from air	As the reef grows out, it leaves a shallow reef flat behind it which can be an important fishing area, as shown by the V-shaped fish traps on this reef flat on Yap. Reefs are an important source of protein food in many tropical areas.
6.	Reef from air	Since fresh water kills corals, there may be gaps in the reef at the mouth of rivers or streams, as here in the reefs of Samoa.
7.	Barrier reef	If the land sinks or the sea level rises, the reef may keep growing up to the surface but farther offshore, making a barrier reef such as this one in Palau with a deep lagoon behind it.

8. Rose Atoll

A volcanic island may sink completely beneath the surface while the reef keeps growing, leaving only a ring of coral reef which makes an atoll with a lagoon in the middle. This is one of the smallest, Rose Atoll, in American Samoa.

9. Atoll islet

The land on atolls is made by coral sand and rubble piled up on the reef flat by waves and storms to make low islands only a few metres above sea level such as here at Kayangel Atoll near Palau.

10. Part of atoll from air

Some atolls like Butaritari in Kiribati may be very large, with long narrow islands on the reef surrounding lagoons of hundreds of square kilometres in area.

11. Manuae Atoll

The atoll lagoon may be deep and open to the sea, shallow and nearly filled with sand, as here at Manuae in the Cook Islands, or even closed completely by the reef with water fresher or saltier than sea water.

12. Nauru

Occasionally an atoll or reef may be lifted out of the water to make a raised coral limestone island, like Nauru shown here.

13. Cliffs, Niue

The former coral reef then becomes cliffs into which the waves begin to cut. This picture was taken on Niue, another raised atoll.

14. Elkhorn corals

When conditions are right on a young coral reef, fast-growing corals like this elkhorn coral may help it to grow rapidly to the surface, as here on Glover's Reef, an atoll in the Caribbean.

15. Reef crest

Since corals cannot grow above the surface, the reef stops growing upward, and fills in to make a solid reef crest like this on the barrier reef of Belize in Central America.

16. Reef crest

Since this part of the reef receives the full shock of the waves, most corals are not strong enought to grow there, and their place is often taken by coralline algae which cement the reef together.

17. Algal ridge

These stony algae may build up the edge of the reef in the wave zone, making an algal ridge such as here on Tutuila Island, American Samoa.

18. Rose Atoll from air

The coral reef makes a breakwater, reducing the force of the waves and protecting the land from erosion, while the reef animals and plants take from the moving sea water the food and materials they need to grow. The pink color of the coralline algae is particularly visible here on the reef of Rose Atoll.

19. Reef from air

A reef may be more or less straight or regular in shape, depending on the form and slope of the bottom. The reef here off Savaii in Western Samoa is irregular because the bottom slopes very gently.

20. Back reef from air

Pieces of broken coral and sand from the reef will be carried back by the waves, filling in the area behind the reef to make shallow back reef areas like this one in the Bahamas.

21. Back reef with grass

These back reefs may be covered with algae or seagrasses producing food for fish and other animals. This is on the Belize barrier reef.

22. Back reef from air

Here in American Samoa there are corals growing on the back reef where it drops into the deeper lagoon. A reef like this may grow on both its outside and inside margins.

23. Lagoon patch reef

Different types of corals and reefs grow in the more protected waters of the lagoon, like this patch reef in the lagoon of Aitutaki, Cook Islands.

24. Lagoon corals

Shallow lagoon floors such as here in Kayangel Atoll may be covered with thickets of corals.

25. Islet reef

There may also be fringing reefs along the land or around islets inside the lagoon, like this one on an islet in the lagoon of New Caledonia.

26. Forereef from air

The richest coral growth may often be on the outer front or slope of the reef where it drops into deep water. The clear ocean water allows the light necessary for reef growth to reach the bottom tens or hundreds of metres deep.

27. Forereef slope

The corals on the reef front slope like these at Munda in the Solomon Islands grow over each other in their efforts to get the most light and food. At the same time they provide shelter for the fish and other organisms on the reef.

28. Corals on reef slope

The variety of forms and shapes of corals can be very rich. On a healthy reef like this at Ant Atoll near Ponape the corals may completely cover the bottom. The coverage of living coral is often used as a measure of the health of a reef.

29. Diver on reef slope

It is the stony coral skeletons that provide most of the material for building the reef. The amount of living coral therefore determines how fast the reef can grow. This is a very rich reef in Palau.

30. Diver on deep reef

The lower limit of coral reef development may be determined by the presence of a sandy bottom to which corals cannot attach, or by the depth to which enough light penetrates (which depends on how clear the water is). Here in Belize there is often a sandy shelf at over 20 metres depth.

31. Deep coral community

Such deep coral communities may still include many kinds of corals, algae and animals living closely together.

32. Deep coral growth

Here in Palau the is extensive coral development goes very deep. However in some places where the reef has sunk faster than the corals can grow, a reef may be "drowned" and no longer be able to reach the surface.

33. Branching corals

There are hundreds of kinds of corals with many different forms, such as these with many narrow branches in Palau.

34. Staghorn coral

Looked at closely, you can see the tiny holes where the individual coral animals live in the colony. This common type of branching staghorn coral is one of the faster growing corals; its branches might grow 100 millimetres in a year.

35. Table coral

Other corals like these table corals in Samoa form flattened sheets on a central pedestal or sticking out like a shelf from a vertical surface.

36. Foliose coral

Some coral colonies are made up of leaf-like sheets sticking up from the bottom. On this coral in Belize, some algae are sheltering between the sheets where grazing fish cannot reach them so easily.

37. Reef with solid corals

Corals like these in the Solomon Islands may form solid massive heads. They may grow more slowly than more delicate corals, but they are very resistant to wave and storm damage.

38. Solid coral pinnacle

Some solid corals form knobby growths as if reaching up for the light coming from the surface. All reef-building corals require light in order to grow well, because they depend for much of their food on tiny plants or one-celled algae living inside the animals. The plants and animals help each other in what is called a symbiosis; the algae feed the coral animals, and the corals house, protect and fertilize the algae.

39. Close-up of solid coral

Looked at closely, it is again possible to see the holes where the coral animals live. The stony skeleton they make around them helps to protect them from the waves and the many hungry things on the reef. The color of a coral comes from the algae living inside the coral animals. If the coral dies, its skeleton turns white before being overgrown by other kinds of algae like all other rock on the reef.

40. Close-up of brain coral

This solid coral is called a brain coral because the animals live in grooves that resemble the surface of the brain.

41. Fire coral

Swimmers and divers usually recognize the fire coral, a close relative of the true corals, because it can sting them if they touch it. While all corals can catch food by stinging tiny animals in the water, only the fire coral has a sting strong enough to go through our skin.

42. Coral polyps

This close-up view shows the little white coral animals or polyps out feeding on the Australian Great Barrier Reef. The food they catch gives them both energy and important nutrients which they can pass on to their symbiotic algae.

43. Polyps extended

Each of these extended polyps shows the typical form of a coral animal. The cylindrical body has a mouth in the middle surrounded by a ring of tentacles or arms covered with stinging cells which paralyze their prey so they can pull them into their mouth and eat them.

44. Young coral

Corals reproduce by releasing tiny swimming stages that look for a good place to settle down and grow into young corals like this one. It is not easy on a reef to find space that is not already occupied, and this can make it hard for corals to re-establish themselves after they have been killed off or the reef has been damaged.

45. Giant coral

On the other hand, under good conditions, some corals like this one on the Great Barrier Reef can live to be hundreds of years old. This coral only grows a few millimetres a year, and it has reached a diameter of more than 2 metres.

46. Soft corals

Not all corals have stony skeletons that help to build the reef. These soft corals in Samoa feel rubbery to the touch.

47. Soft corals

Most reefs like this one in Palau have some soft corals, but if there are so many that they replace the stony corals they can keep the reef from growing. On some reefs where the hard corals were damaged, soft corals have taken their place and prevented them from coming back again.

48. Sea fan

There are other colonial animals that live like the corals by catching food in the water, but do not make a stony skeleton. This beautiful sea fan in Belize has a flexible horny skeleton.

49. Gorgonians

All the things in this picture from the Bahamas may look like plants, but they are animals like the sea fans and gorgonians.

50. Coralline algae

This reef rock in Fiji does not look very interesting, but the slight pinkish colour shows it is covered with a crust of coralline algae which may be as important as corals in building a coral reef. Some reefs may even be built more by these stony plants than by corals.

51. Coralline algae

These hard purple knobs from Australia are another kind of coralline algae. The stony crusts of these algae cement the corals and coral fragments together to make a solid reef. Certain kinds even prefer growing where the waves are too strong for corals to live, building the algal ridge at the edge of many reefs.

52. Red algae

It is the plants, of course, that make the food energy from sunlight which powers the coral reef ecosystem. There are many kinds and colours of simple plants or algae on a coral reef, like these red algae from Glover's Reef atoll in Belize.

53. Brown algae

Other algae may be brown, like this one which makes a whitish layer of lime on its delicate fronds to protect them from too much sun.

54. Algae

Algae such as these from Guam can cover important parts of the reef, where they serve as food for the many kinds of reef animals and fishes. Some are thick, tough and slow growing; others are small, delicate and grow very quickly.

55. Brown alga

Some algae like this brown one grow close to the surface to make it harder for waves to tear them off or for animals to eat them.

56. Green algae in coral

The green algae sheltering among the branches of this coral at Heron Island in Australia make a lime skeleton to protect the plant. When they die, the pieces of skeleton are an important source of coral sand.

57. Algal turf

Most surfaces of a reef that are not occupied by living coral or other animals are covered by a fine turf of many kinds of tiny algae. These plants grow very fast and may be eaten just as fast by grazing animals, so even though they may not look important, they may produce an important part of the food energy available on the reef.

58. Turf on rubble

Even loose pieces of broken coral lying on the reef may prove on close examination to be covered by a fine fuzz of algae providing food and lodging for other kinds of tiny creatures.

59. Sea grasses

Sandy lagoon bottoms near reefs may well be covered by beds of algae or sea grasses like these in Puerto Rico. Such areas serve as pastures for fish and other reef animals.

60. Fish over reef

A sample of the kinds of animals on a coral reef will show why it is such a complicated ecosystem. There are many kinds of fish such as these on a reef in Palau, each one living in some different way, often on different kinds of food.

61. Blue fish

Some like these in Fiji may feed on tiny animals or bits of food in the water, and they stay close to the coral where they can hide among the branches if a bigger fish comes wanting to eat them.

62. Damsel fish

The grey damsel fish fiercely defends its little territory so that the algae grow on the dead coral branches and it will always have enough to eat.

63. Fish feeding

There are always fish waiting to nibble on whatever is edible. This wrasse changes its colour and sex as it gets older.

64. Parrot fish

Parrot fish like these in Belize have a beak like a parrot that they use to bite off chunks of coral and rock. They help to wear the reef rock down and make sand, and the little bare places left by their bites may make it possible for baby corals or other organisms to settle and find a place to grow.

65. Clown fish & anemone

The sea anemone and the clown fish are another of the cases of mutual help or symbiosis so common in the coral reef ecosystem. The anemone eats fish, but lets the clown fish hide among its stinging tentacles. The clown fish attracts other fish to be caught by the anemone, and in return receives protection and a share of the scraps.

66. Giant clam

There are many shellfish on the reef, like this giant clam near Lizard Island on the Australian Great Barrier Reef. Like the corals, the clam has algae living under its skin, from which it gets its food in return for fertilizer and protection. Giant clams like this may be almost a metre long, but they are becoming extinct on many islands because they are so easily collected.

67. Starfish

The starfish stick their stomach out to eat whatever they are sitting on. The crown-of-thorns starfish eats corals, and its population explosions in recent years have at least temporarily killed corals on many Pacific coral reefs.

68. Sea urchin

Sea urchins scrape up bits of food and debris they find along the bottom. Their sharp spines defend them against many things that would like to eat them.

69. Sea cucumber

The sea cucumber or beche-de-mer usually prefers sandy bottoms where it can suck up the sand and eat whatever is growing on the sand grains.

70. Worms

There are many worms and other animals that bore holes in the corals or reef rock and live inside, at the same time contributing to wearing down the reef.

71. Sponge

Sponges are very simple animals that pump water in and out to filter out whatever they can find to eat.

72. Orange sponge

They may be brightly coloured like this orange sponge to warn anything trying to eat them that they have many sharp spines buried in their flesh.

73. Beach

All these reef plants and animals together form the coral reef ecosystem which has built many tropical islands and made the pure white sand for many beaches. Since the sand comes from living things, anything that damages the living system will eventually affect the beaches and the islands themselves.

74. Sea urchins in rock

A coral reef is both growing and eroding at the same time. These sea urchins on Rarotonga wear away a hole for themselves in the rock of the reef. A healthy reef has more growth then erosion, but a damaged reef may stop growing and start shrinking, with the loss of many valuable island resources.

75. Dynamited reef

Today more and more reefs are damaged or destroyed by man's activities. This reef in the Truk lagoon was blasted with explosives, an easy but very destructive way of fishing. Any kind of fishing that involves the smashing, breaking or poisoning of corals destroys the very things that feed and shelter the fish being caught.

76. Sedimented reef

Many corals and reefs have been smothered by sediment washed off the land because of land clearing and erosion, as here in Hawaii, or stirred up by construction and dredging. The cloudy water keeps the light from reaching the bottom, so those corals and plants that are not smothered by the silt die from lack of light.

77. Algae covering coral

Pollution is another danger for coral reefs. This reef in Kaneohe Bay, Hawaii, was polluted by sewage, which so fertilized the green bubble algae that it grew over and covered up the corals.

78. Polluted reef

Such a severely polluted reef seems like a nightmare. Fortunately the pollution was removed and the coral reef is now recovering.

79. Airport on reef

Islands are short of land, so coral reefs are often threatened by big construction projects which can destroy the productivity of large reef areas, like this airport runway in American Samoa.

80. The end

Coral reefs are too valuable a resource to be destroyed. We must make every effort to use and manage them wisely.

South Pacific Regional Environment Programme

Training Unit C9

LAGOONS

USE OF THIS UNIT

This unit describes the special characteristics of lagoons which make them places needing careful management. The material is supplementary to the previous unit on Coral Reefs (C8). It can be considered optional or omitted entirely in areas where lagoons do not occur.

While all types of lagoons are discussed in this unit, emphasis should be placed on those types which are found locally, and local examples should be added whenever possible.

EXERCISES

Field trips should be made to as many types of lagoons as are readily available. Opportunities to swim or dive in the lagoons would be especially valuable, as they can give first-hand experience of lagoon environments, and often permit the discovery of phenomena such as thermoclines or salinity differences which are more easily experienced than described.

(Unit written by A. L. Dahl)
[Revision 27/02/85]

TEXT

LAGOONS

Lagoons are common in the coastal environments of many islands. They are areas of water with some link to the sea, but sufficiently cut off or protected so that there are special environmental conditions inside them. They therefore present special problems for environmental management.

Types of lagoons

The type of lagoon depends on the form and origin of the island and often the stage of coral reef development, since it is often coral reefs growing up to the surface that cut off and protect an area of water, making a lagoon. Even a fringing reef may have a depression between the reef crest and the shore, forming a narrow shallow lagoon. A barrier reef can be up to several kilometres offshore, creating a large lagoon which may be tens of metres deep and contain islands and patch reefs. Most atolls are more or less circular in form, with the atoll reef enclosing what can be a very large lagoon. If the reef is not complete, the lagoon may be very open on one or more sides, or it may be joined to the sea by channels or passes through the reef. If the reef is well developed, or the atoll has risen slightly, the lagoon may lose all surface connection with the sea.

Sometimes a lagoon may be made by the shape of an island or a group of nearby islands creating protected areas of water. Shallow coastal lagoons may be created when a low-lying area of water is more or less cut off from the sea by mounds of sand or rubble piled up by storms or waves.

A related type of environment is the estuary, the enlarged area at the mouth of a river where the fresh-water from the river mixes with the salt-water from the sea.

Because lagoon waters are protected they are more accessible to man. They may be very productive, and thus are important fishing areas. At the same time, towns and villages are often built along lagoon shores, and they may be developed as ports. These activities can create important conflicts.

The lagoon environment

Lagoon environments differ in a number of ways from other coastal waters. Where the exchange of water with the ocean is limited, the ocean can no longer exert its stabilizing influence on the temperature. Lagoon temperatures tend to be more variable and more extreme than in the adjacent ocean. The shallow water mass of the lagoon is more easily heated by the sun during the day, and cooled by radiation and evaporation at night. After a long day in the full sun, lagoon temperatures can rise quite high. If the lagoon is deep enough, and the water mixing caused by the wind does not reach to the bottom, then a thermocline may develop. This is when the warm surface water lies on top of the deep cooler water, and the sharp difference in temperature between the two keeps an exchange of water from taking place. If you dive

through a thermocline, you can feel the water suddenly get colder. The high and variable temperatures in a lagoon may limit the kinds of plants and animals that can live there.

The salinity, or saltiness, of the ocean changes very little. However, in a lagoon, the salinity can also be more variable. Heavy rainfall may dilute the water of the lagoon, making it less salty. Water draining off the land,or coming down rivers and streams may also dilute the lagoon. The less the lagoon is connected to the ocean, the more extreme the effect will be. Sometimes the fresh-water will even float in a layer on top of the salt water, and you can see a "blurred" zone where the two mix. If a closed lagoon receives a lot of sun and very little rain, than the opposite may take place. The evaporation of the lagoon water can increase the salinity well above that of the surrounding ocean. Again, the kinds of marine life that can live with wide changes in salinity are limited.

Water movement can also be more limited and more variable in lagoons. Waves may enter the lagoon through passes or channels, or they may occasionally wash over the reef. As the tide rises and falls, there may be flows of water into and out of the lagoon, with very strong currents in the passes. Large lagoons may have currents driven by the prevailing winds. However, in general, lagoons provide a shallow environment protected from the extreme water movement of wave-swept shores.

Lagoon life

Lagoons that are open to the sea may have many of the same corals, fish and other sea life as the ocean itself. As the conditions in a lagoon get more variable and more extreme, the number of kinds of things that can live there will get smaller and smaller, although those things that can live there may get to be more common.

The life of lagoons may be more productive and abundant than in the sea outside if there are nutrients that go into it from the land, or if it is able to accumulate nutrients because it is protected. The shallow lagoon bottom is often covered with beds of seagrass or seaweed, and reef corals may grow on the lagoon edges and on patch reefs within it. It may provide important breeding or feeding areas for fish or other animals outside the lagoon as well.

Some lagoons support fisheries that are very important for the island. They may have bait fish that can be used to fish for tuna. Certain lagoons have important beds of pearl oyster. Others may have shellfish that are collected locally for food.

If a lagoon becomes too closed, however, there may not be enough water exchange and the lagoon may become stagnant and support much less life. There may even be no oxygen left on the bottom for animals to live.

Because the lagoon environment is often less stable, there may be big changes in the kinds of plants and animals that grow there. Something may multiply until it seems to be everywhere, then it may die off, to be replaced by something else. These changes may follow the seasons, or they may happen without any apparent reason.

Vulnerability to changes

Lagoons, like the islands of which they are a part, may go through important changes over a long period of time. The coral reef may grow up and cut them off more and more from the ocean. They may gradually fill up with sediment until they become part of the land. If the island is sinking, a lagoon may gradually lose its protective barriers and become part of the ocean shoreline; if the island is rising, the lagoon may be lifted up until its bottom is dry land. Sometimes a natural change may seem sudden, as when a growing reef finally stops the flow of ocean water into a lagoon and its water quality and populations change very quickly, but usually these changes are so slow that we hardly notice them.

When man decides to change a lagoon, he can do it much faster. Often the need for a port or for better boat access means dredging part of the lagoon bottom, clearing coral heads and patch reefs, constructing wharves and other facilities along the shore, and making or enlarging channels or passes. A dredged bottom will never be as productive as the natural one was, and the sediment that is stirred up may smother areas that are not directly affected. The explosives necessary to remove coral heads or enlarge channels also kill many fish. Making a bigger channel may change the patterns of water circulation in the lagoon. Building a causeway between islets may cut off flows of water important to maintaining the quality of the lagoon, and can even block the migration routes by which fish go in or out to feed. All these changes will have their effects on lagoon life and productivity.

Wastes and other runoff from the land may also collect in a lagoon and pollute it. Some islands have had cholera epidemics spread by the pollution of seafood caught in the lagoon. Lagoons are particularly vulnerable to the development of towns or cities around their edge.

Since a lagoon is usually a single system, the whole lagoon is usually affected by damaging activity. It is not usually possible to reserve or protect just one part of it.

Lagoon management

Lagoons generally have to be managed as a whole for multiple uses. Each activity has to be developed carefully to be sure it fits with all the other uses.

The way the lagoon system works must be studied in detail before deciding to make major changes. Since each lagoon is different, it is hard to judge how one lagoon will behave by comparing it with some place else. Since most lagoons have many variables and our knowledge of them is limited, it is hard to predict what effect a change may have. If lagoon productivity is important for local people, any new inputs or changes must be carefully controlled. Only in this way can lagoons continue to be useful resources for island people.

QUESTIONS

Is there a lagoon on your island? How was it made?

What is the lagoon water like in comparison with the ocean? Warmer? Saltier? Not so clear?

How does water go into and out of the lagoon?

Do you know how the water moves inside the lagoon?

What kinds of plants and animals are common in the lagoon?

Are they always the same, or do they change?

Do you know of fish or animals outside the lagoon that depend on it in some way?

What important things do you take from the lagoon?

Has the lagoon always been the way you know it now?

Can you think of any ways it has changed?

Has the lagoon been affected by man-made changes?

What are they and what have they done to the lagoon?

What needs to be done to manage the lagoon wisely?

South Pacific Regional Environment Programme

Training Unit C10

MANGROVES

USE OF THIS UNIT

Mangroves are an important coastal resource in most of the western Pacific, and this unit will therefore be important for those countries where mangroves occur. Since many people have been taught to think of mangroves as bad, this unit emphasizes the usefulness of mangroves in the island system and the special problems they present for environmental management. The content of the unit should be reinforced with as much work in the field as possible, assuming there is access to mangrove areas.

AUDIO-VISUAL SUPPORTS

The IUCN slide-tape programme "Understanding Mangrove Ecosystems" is highly recommended to reinforce and expand on the content of this unit. It can be borrowed from the South Pacific Regional Environment Programme, or purchased from the WWF/IUCN International Education Project, Greenfield House, Guiting Power, Cheltenham, Glos. GL54 5TZ, United Kingdom, for approximately US$20.00.

EXERCISES

Field trips should be made to as many types of mangroves as may be accessible. Sites where mangroves have been damaged or destroyed should also be included if possible. The principles raised in the unit can then be explained with reference to local examples. Local fishermen and other users could also explain what they take from mangrove areas.

If the water is not too muddy, facemasks or a glass-bottom bucket may make it possible to see baby fish or other animals in the water.

SUPPLEMENTARY MATERIALS

A number of useful references on mangroves and their management are available and can provide supplementary information for use in areas where mangroves are important:

Handbook for Mangrove Area Management, edited by L. S. Hamilton and S. Snedaker. Published jointly by East-West Center, IUCN, UNESCO and UNEP, 1984.

Global Status of Mangrove Ecosystems, edited by P. Saenger, E. J. Hegerl and J. D. S. Davie. IUCN Commission on Ecology Papers Number 3, 1983.

Management and Utilization of Mangroves in Asia and the Pacific. FAO Environment Paper 3, 1982 (Mostly on utilization and only 3 pages on the Pacific).

(Unit written by A. L. Dahl)
[Revision 28/02/85]

TEXT

MANGROVES

Mangroves are a group of unusual trees that can live in salt water from the oceans. Most land plants are killed by salt, but mangroves are able to get rid of the salt. Most plants die if their roots are drowned in water and have no oxygen, and in the mud of mangrove swamps, the rotting leaves usually use up all the oxygen. However mangrove trees have developed special kinds of roots that stick up out of the mud into the air to get oxygen. As a result, mangrove forests (or at least a fringe of mangroves) are common along the coasts of many tropical islands wherever the shore is soft and muddy enough for them to take root.

In the Pacific, the number of kinds of mangrove trees is greatest in the west, and gets smaller going to the east across the Pacific until the mangroves disappear. Mangrove forests in the western Pacific are bigger and richer, with different kinds of mangroves growing under different conditions. Some mangroves prefer water that is not as salty as seawater, and they are thus more common at the mouths of rivers where fresh-water and salt-water mix.

Usefulness of mangroves

Most people have thought of mangroves as noxious impenetrable swamps full of diseases, and they used to be destroyed as a public health measure, but now we know better. Mangroves are very productive coastal resources that are useful in many ways. Mangrove trees grow well in their special conditions, and, like the tropical forest, they produce a lot of leaves and other organic matter. Instead of accumulating in the soil, the leaves fall in the water, where they rot and provide food for microbes and many tiny animals. This rich food is not only eaten in the mangrove swamp, but much of it may be carried out into the lagoon or to coral reefs and other coastal fisheries areas, where it helps to feed the fish. The areas near mangroves are thus often very important for fishing.

Because there is lots of food in mangrove areas, and good shelter among the mangrove roots, some kinds of fish come there to reproduce, and many baby fish grow up there before going to live in the lagoon or on the reef. The mangroves are a critical habitat upon which these species depend for survival, and if something happens to the mangroves, the future of these kinds of fish will be affected.

Mangroves also build land or keep it from being washed away, which can be very important on islands where land is so limited. Mud and sediment are often washed down rivers and streams. When there is a mangrove swamp at the river mouth, the water spreads out into the mangroves, and the sediment settles to the bottom where it is trapped by the mangrove roots. As the bottom gets shallower, the mangroves can grow further out, while those on the inside eventually find themselves on dry land, where they are replaced by land plants. In this way the mangrove forest advances slowly outward, leaving land behind. Even in areas where there is not enough sediment to

build new land, the mangroves protect the shoreline from being washed away in storms. The roots and trunks break the force of the waves, and the leaves and branches reduce the effects of the wind and rain. There are examples of islands which were built by mangroves, and then washed away when the mangroves were cut.

Mangroves are an important source of food and materials for many coastal people. Crabs, clams, oysters, fish and other food are often collected there. Even the mangrove fruits are sometimes eaten. Mangrove wood is often collected as firewood, and it can also be used for building. The bark has tannin which has craft and medicinal uses.

Even in the city, mangroves can be important. The city wastes run off and pollute the nearby coastal waters. When the wastes from all the people run into a mangrove swamp, they can be taken up and used by the plants and animals in the swamp. In a way the swamp filters the water, leaving clean water to go out the other side. As long as there is not too much waste for the mangroves, and no poisonous wastes from industries, the mangroves are an excellent waste treatment system, and much cheaper than a sewage treatment plant.

Threats to mangroves

Unfortunately in spite of their usefulness, mangroves are being destroyed in many places. Sometimes they are drained as a sanitary measure, although mosquitos, for instance, do not like the salty water of most mangrove swamps. Often mangrove areas are used to dump rubbish or garbage. On islands where unoccupied land is in short supply, mangroves are often cleared to make agricultural land, or filled in for construction. Large areas have been lost to development in this way. However, such low-lying land may be vulnerable to flooding in storms, so the development is not always so successful.

In some places mangroves are cleared to make aquaculture ponds for raising fish or shrimp. Ponds may also be built to treat the wastes from cities, towns or factories. Other kinds of construction can also damage mangroves. Anything that changes the way water circulates or its saltiness can kill the affected mangroves. Taking water from rivers for irrigation can reduce the amount of fresh-water available to mix with the salt-water. Frequently a causeway for a road, or some other construction project, may keep the sea-water from coming into the mangroves. As the sea-water is replaced by fresh-water, the mangroves will die.

Mangroves are also sensitive to pollution, particularly oil pollution. If an oil spill goes into a mangrove area, the oil covers the aerial roots, and the tree roots can no longer get the air they need to live. The roots will die, and with them the whole forest. Mangroves are also very sensitive to herbicides.

With all these different threats, and the fact that few people appreciate how important the mangroves really are, it is no wonder that the area of mangroves is getting smaller. The steady reduction in mangroves means the loss of an important resource. As each little bit is taken, the remaining natural area becomes that much more important for such things as fish breeding and nursery areas. On some islands, only tiny areas of mangroves remain. Their loss could be a tragedy for coastal fisheries.

Mangrove management

On islands where many different needs must be fit together, the careful management of mangrove areas is important. If there are large areas of mangrove forest, then some parts can probably be developed, allowing for a balance of uses. Special attention needs to be paid to the percentage of the total area developed, and to avoiding critical breeding habitats and other areas of particular interest. Where only small areas of mangrove remain, they probably should be protected.

Every effort should be made to avoid changes in salinity or water circulation in mangrove swamps. If a road needs to be built through a swamp, enough bridges or culverts should be provided to allow water movement into and out of the swamp. In areas where sedimentation is important, the mangroves should be allowed to go ahead with their stabilizing and protective role. Similarly mangroves should be strictly protected wherever they are important in controlling coastal erosion.

Because of their vulnerability to oil pollution, mangroves should receive special attention for protective measures in oil spill contingency plans. Oil loading and storage facilities should not be located near mangrove areas.

Not all uses of mangroves will go together. A forest that is heavily cut for firewood will not produce as much food for the lagoon and reef. The mangrove areas in a city that are used for waste treatment should probably be closed to fishing to avoid the danger that shellfish or other seafood from the area might pick up and spread diseases.

Fortunately a mangrove forest can often be replanted if it is damaged, just like a forest on land, assuming that the conditions are still good. Where temporary damage at a construction site cannot be avoided, at least the trees can be replaced afterwards. It is even possible to require a developer who destroys part of a mangrove swamp to replace it with an equal area somewhere else, so that the total area of mangroves does not change. However, it is much easier to keep the mangrove that is already there than to try to replace it once it has been lost.

QUESTIONS

Are there mangroves in your area? What are they like?

What is unusual about a mangrove forest?

How can mangrove roots live in the swamp mud where there is no oxygen?

Why do many people think mangroves are bad? Is this true?

Why are mangroves important for baby fish?

How do mangroves build or protect the land?

What are other ways that mangroves are important?

What are the most important uses of mangroves in your area?

What are the threats to mangroves?

Have mangrove areas been lost where you live? Why?

How much of the original area of mangrove still remains on your coast?

Is anything now being done to manage your mangroves?

What do you think needs to be done so that the mangroves will meet all of your requirements?

Do you know of places where it might be good to replant mangroves?