marine education trust

explore the sea

a resource pack to introduce young people to the coasts and seas of coral reef ecosystems

by
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Explore the Sea

Introducing young people to their coasts and oceans

According to the Center for International Earth Science Information Network (CIESIN), 39% of the population of the Earth live within 100km of the coast. Many of these people, and those who live further from it, use the oceans as a source of food, of mineral resources or timber, as a site for recreation and, unfortunately, as a dumping ground for wastes. As the human population expands the pressures on our fragile marine ecosystems will become ever more intense.

Against this background it is increasingly important that, as the future stewards of the marine environment, young people understand the sea and contribute to its sustainable management. The key to fostering a sense of stewardship and responsibility in young people, and through them in communities as a whole, is through practical, hands-on education that teaches them to cherish the fascinating, exciting and endlessly variable sea and its wildlife.

The purpose of this pack is to provide a series of activities to teach young people about the different habitats, marine life and environmental pressures affecting the tropical coral reef ecosystems. They are primarily designed for the western Indian Ocean islands of Rodrigues, Mauritius, Madagascar, the Comoros, and the Seychelles, but can easily be adapted for other locations.

The activities were inspired by the *Club Mer* Marine Ecology Course, which was introduced on the island of Rodrigues by the Royal Geographical Society's *Shoals of Capricorn Programme* in 1999 and is continued today by Rodriguan NGO *Shoals Rodrigues* (http://shoalsrodrigues.net). *Club Mer* is a marine environmental education club for young people, which has touched many of Rodrigues' teenagers, some of whom have gone on to have fulfilling careers in marine science and education. *Club Mer* was also the seed that inspired the creation of the Marine Education Trust (www.marineeducationtrust.org), as the team behind MET were involved from the start of *Club Mer* and *Shoals Rodrigues*.

Who can use these resources?

Anyone can use these resources, but they are aimed primarily at young people from 13 to 18 years of age. The general standard assumes at least primary-level education but there are activities to suit all abilities and levels of commitment.

The resources suit formal and informal teaching styles and it is hoped that they will be used by wildlife and conservation groups, youth clubs and schools. It is assumed that the leaders who use these materials have at least a secondary school level understanding of biology. That said, enthusiasm, curiosity and a passion to educate young people in marine conservation issues, are as important as any formal science qualifications.

Contents of the resource pack

- Introducing ecology
- Reefs and lagoons
- Sandy shores
- On the rocks
- Marvellous mangroves
- The open ocean
- Conservation concerns

How to use the materials

This is not a conventional marine ecology course. We have not attempted to produce anything which is complete or definitive or which should be delivered in any particular order. Instead, we have provided ideas for practical activities which can be used to help encourage young people to explore their local marine environments, and to be excited by what they find. We hope that through raising their understanding and enthusiasm of marine conservation issues we can improve community awareness of the issues raised.

Explore the Sea is not a textbook: the focus of the pack is very much the provision of practical activities. Some relevant background information is provided to introduce the concepts behind the activities, but it is expected that course leaders will also have access to identification guides and other reference material.

The resources are arranged into sections and it may make sense to use some before others, but you should feel free to pick and choose the resources which suit your own circumstances and the facilities which you have to hand. Some of the investigative activities will require simple laboratory equipment, but if you do not have this you can simply leave out that particular activity.

Each topic contains Educators' Notes for those leading the course, and Student Activity Sheets. You are free to copy and distribute these however you please, provided that they are not offered for sale and as long as the Marine Education Trust is acknowledged as the author of the material.

The topics are not of equal length and the activities can either be done in the classroom, at home or in the field, depending on what they are. Some marine habitats, such as sandy and rocky shores, can be visited easily, whereas others, such as the open ocean, cannot. We have intentionally included much more material on ecosystems which your students can experience themselves.

Educators' notes

You do not need to have any previous experience or expertise in marine ecology to be able to teach this course. The Educators' Notes for teachers and group leaders explain what you need to know to lead the activities. They also include some tips on how to make activities run well and the all-important answers to the quizzes!

Slideshows and presentations

In classroom sessions to introduce the activities, presentations that illustrate the creatures and concepts being discussed can be very useful.

Our experience has taught us that slides with a lot of writing on them are boring and often present far more information than students can possibly retain. Images, on the other hand, are exciting to view and provoke discussion, which is far more valuable to improving understanding than simply presenting facts to be memorised. Use them as a stimulus for interaction with your young people, don't just deliver a lecture.

Projecting slides onto a large screen helps, but if you do not have access to a projector you can still show them on a PC screen to smaller groups. Even printing out images and showing them that way helps to illustrate a talk.

If your students have access to computers then don't forget they can write and present their own presentations to the rest of the group. If they do this remind them that the secret is more images and less text!

Student activity sheets

There is a wide variety of different activities suggested. Each activity sheet lists the materials and equipment needed but you should feel free to make sensible substitutions. The equipment needed includes art materials, basic laboratory and fieldwork equipment and, very occasionally, chemicals which should be available from hardware stores or a school science lab.

Activities include the following:

- **Classroom activities** include role-playing, brainstorming, debate, art and craft activities, games and quizzes.
- **Laboratory activities** include simple scientific experiments.
- **Activities in the field** include spotting, catching and identifying plants and animals *in situ* and surveying intertidal habitats.
- **Activities at home** include researching sea-related traditions and interviewing family and friends.

Remember, the activities are not intended to be delivered in a particular order (although it makes sense to use some before others). Pick and use the activities which you think your young people will enjoy and which match their age and abilities. Feel free to make activities more challenging for older students and use the simpler ones with younger children.

Although the activities are divided into sections some can be equally useful in different ecosystems. The "Bird Diary" activity, for example, could be carried out on a sandy shore, a rocky shore or in a mangrove. Food webs are important in all ecosystems but will include different plants and animals, so some activities could be used several times in different habitats.

This course is designed to stimulate interest in the marine environment. We want the students to want to know more. Don't worry if they ask questions you cannot answer. Encourage them to increase their knowledge and interest from books and the internet. Who knows where it might lead them!

Health and safety

The safety of your students is extremely important and you should never undertake any activity without considering the possible risks and hazards they might experience. This will vary from cutting themselves with scissors during an art project to being cut off by the tide on a trip to the reef. Some of the activities are likely to expose students to unfamiliar environments and none can be guaranteed completely safe. It is your responsibility to ensure the safety of young people in your care.

Before undertaking any field trips we recommend the following

- Visit the site beforehand and note any potential hazards
- Check tide tables and weather forecast
- Brief students about any dangers beforehand and tell them if they need to bring any particular items such as shoes, hat or sunscreen
- Bring plenty of water
- Always tell someone where you are taking your group and when you will be back
- Always have at least two leaders so that one can deal with any emergency whilst the other keeps control of the group
- Expect high standards of behaviour from your young people
- Ask for advice if you are unsure!

What to do when you run out of activities

Please invent your own activities and tell us about them. The Marine Education Trust website (http://www.marineeducationtrust.org) will be updated from time to time and new activities will be added. We would love to include your new ideas!

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Introducing Ecology

Central to a better understanding of the marine environment is appreciating why different animals and plants live in particular places and how those found in the same environment interact with each other. The reasons why a certain area is appealing to particular plants and animals can be revealed by considering the availability of food and shelter and the range of physical conditions such as light and temperature. Having determined what it is that may have attracted the different creatures, ecologists then consider how they behave towards each other. Which animals eat which others (and how they avoid being eaten themselves) is often of particular interest, although there are other relationships between different animals that do not necessarily result in one becoming a meal.

Marine ecology is different

We are land animals. It is hard for us to begin to understand what it is like to live in the sea. Sea creatures have to face all sorts of problems, quite strange to us. The same principles as for terrestrial ecology apply but it is certainly more challenging to live in the sea. Even those familiar seashore plants and animals, such as crabs, snails and seaweed, have to put up with the tide going in and out, sun and wind, and the force of crashing waves. Under the sea the main factors that decide what lives where are depth and light, currents, food, competition and the type of seabed.

The Physical Environment

The Tide

Sea level is not constant. The gravitation forces of the moon and, to a lesser extent, the sun cause the tide to rise (or **flood**) and fall (**ebb**) in a way that is rhythmical and entirely predictable. Marine life that lives on the shore has to deal with being fully covered by seawater and also being exposed to the air, when the temperature can become much higher and they risk drying out. To cope with these changes, animals may hide in cool, dark crevices in rock, burrow in the sand, or those that can't move will close their shells to remain cool and damp.

The amount of beach that will be uncovered is not the same every day. Very high and very low tides (**spring tides**) happen at full and new moon, when the gravitational forces of the sun and moon combine. **Neap tides** occur in between when the sun and moon are perpendicular, each slightly cancels out the gravitational influence of the other, and so the difference between the tides is smaller. The transition from spring tides to neap tides is gradual, with the tidal range becoming a little larger, or smaller, every day.

Animals and plants found at the top of the shore will be used to daily covering and uncovering by the tide, while creatures lower down the beach may only be uncovered once or twice each month or for just a few days over the course of a year.

Currents

The tide and the shape of the shore are fundamental components driving local currents. The incoming and outgoing tide will race particularly fast through constrictions such as channels between the shore and islands or through passes in the reef. There are also huge currents driven by large climatic forces, which affect water movement on a regional or even global scale.

Many creatures in the sea release eggs and sperm into the seawater. The fertilised eggs, and the microscopic larvae that develop from them, are carried along by the currents, which therefore have a big influence on where the adult animal ultimately finds itself living.

Currents also have a role in providing food to the many **sessile** creatures, like barnacles and clams, that do not move around because they are fixed to, or buried in, the seabed. Many of these are **filter feeders**, that strain their food of **plankton** (tiny floating plants and animals) and other nutritious particles out of the surrounding seawater. They need constantly moving water to ensure a continuous supply of fresh food.

Depth and Light

Sunlight, shining down on the sea, is absorbed by the seawater as it goes down. In shallow water there is plenty of light but as you go deeper it gets dimmer and dimmer.

Seagrasses, seaweeds and the algae living within the corals, like all plants, need sunlight to grow. They get their energy from the sun. Animals such as sea snails that eat seaweed are also found in shallow water, as they have to live where their food is.

Some animals that live in areas where the light begins to fade use these difference in light levels for camouflage. They have silver bellies so that when seen from below they merge against the brighter surface, and they have dark backs so that from above they cannot be seen against the gloomy depths below.

There are plenty of animals that live at depths where there is no light at all, and they are specially adapted to this environment. Some have enormous eyes to make use of any tiny glimmers of light, while others have no eyes, and yet more make their own lights.

The Seabed

People who have not had the chance to see what the sea is like below the surface often make the mistake of thinking the seabed is a flat, sandy desert. In fact, there is a rich and varied seascape. There are reefs of rock or coral with overhangs, caves and crevices; seagrass meadows; sandy plains; coarse gravelly areas; boulders and cliffs. All these provide a **habitat** – 'a home' – for **communities** of marine life.

The type of seascape affects the community that lives there. Seaweeds, and animals such as barnacles, sponges and sea firs, which need a hard surface to attach to, are found on reefs and rocks. Lobsters and crabs like to hide in cracks, crevices and caves. Sea squirts and fan worms, which like shady places, are found under rocky overhangs, and burrowing animals like worms and cockles inhabit soft sand or gravel.

The type of seabed and shoreline is a factor of the local bedrock (limestone or basalt), anything carried into it from elsewhere (land run-off carried by rivers, for example), and the strength of waves and tides. Strong waves and fast currents can wear down rock or carry away any fine particles, while quiet water will allow fine silt and mud to settle onto the seabed.

Species interactions

Food

Where animals live tends to be driven by what food is available. Some creatures, called **opportunists**, have a varied diet and can take advantage of whatever food source is available. Other animals eat only one particular type of food, for example the purple butterflyfish that only eats coral. This very limited diet makes **specialists** more vulnerable to changes in their environment: if their food source disappears then they soon vanish too.

Competition

Marine animals compete for space and food. The more competition there is for food, the less chance there is of getting your share. Different types of animals therefore have special design features – we call it **adaptation** – to live and succeed in a particular place (**niche**). This adaptation might give them an edge over competitors. They might be camouflaged to sneak up on their prey or to prevent a predator spotting them. They might be specially adapted to burrow.

If animals are adapted to live in particularly difficult conditions, like in areas of very strong currents, or at the top of the beach where they are hardly ever covered by the sea, then they have less competition to worry about!

Defence and Camouflage

Animals go to great lengths to avoid being eaten by other creatures. They may have hard shells, sharp spine, carry poison in their tentacles or, in the case of pufferfish, suck in water and puff themselves up so they appear much larger and the predator may think twice. Some animals can quickly regrow their body parts: starfish will sacrifice one of their legs in order to escape being eaten completely and sea cucumbers can expel their intestines to cover their attacker in a mass of sticky threads. Safety in numbers is employed by many species of fish, as it is hard for a predator to single out one fish amongst a swirling mass of identical ones. Others animals hide in crevice or burrows, or in plain sight by using camouflage. This can be straightforward trickery, such as mimicking the colour patterns of a poisonous species, or else, in the case of octopus and flatfish, can involve changing skin pattern or colour to blend in with the seabed.

Predators employ these sort of tricks too. Octopus themselves are hunters as well as a possible food source for others. Stonefish sit on the seabed looking like seaweed-covered rocks and wait for their prey to come to them, while deep-sea angler fish attract their prey with a lure of light.

Partnerships

Marine creatures have many relationships other than just predator and prey. Sometimes these only benefit one party. At best, **parasites** do little damage to their host, such as the barnacles that hitch a ride on whales or turtles. Others, like the sea lice that attach to, and feed on, fish can be harmful and even ultimately kill their hosts. In **commensal** inter-species relationships, there is benefit to both animals. Certain shrimps and small fish provide a cleaning service and remove parasites from larger fish in return for not becoming their prey. Other animals may share a home, as is the case with the burrowing shrimp that does the digging, and its goby housemate that keeps a look out.

Terminology

While specialist terminology is best avoided with young children, there is no reason to shy away from it with teenagers. Specialist terms have evolved not because scientists try to be exclusive, but because they are an effective shorthand for longer explanations – it is far simpler to say 'photosynthesis', for example, than to continually have to refer to 'the process by which plants get their energy by converting sunlight and carbon dioxide and from which oxygen is a byproduct'.

Scientific terms are widely used, so if the students are doing any research on their own or just learning more because they are interested, then they will need to understand what these important words mean. Learning to properly use these kinds of terms is also part of their wider education in science.

The glossary below is by no means exhaustive, but includes some common scientific terms which the group are likely to encounter as they delve deeper into marine ecology.

Marine - Refers to the ocean.

Environment - The place in which a plant or animal lives, and the circumstances under which it lives.

Organism – A living plant or animal.

Species – A single type of organism.

Genus – A group of closely related organisms that share common characteristics.

Ecosystem - All the organisms in a particular region and the environment in which they live. The elements of an ecosystem interact with each other in some way, and so depend on each other either directly or indirectly.

Habitat - The place and conditions in which an organism lives.

Niche - The portion of the environment, which a species occupies. A niche is defined in terms of the conditions under which an organism can survive, and may be affected by the presence of other competing organisms.

Adaptation – A feature or features that make an organism able to survive within its environment.

Benthic – Plants and animals that live on the bottom of the ocean are called benthic organisms.

Pelagic - Pelagic organisms swim through the ocean, and may rise to the surface, or sink to the bottom. They are not confined to live on, or near, the bottom as benthic organisms do.

Sessile - Not moving. Many organisms, both plants and animals, spend the majority of their lives in one place.

Nocturnal - Active only at night.

Dispersal - Spread of a species to a new location. In many organisms, this happens at a particular stage in the life cycle, and is often crucial to the survival of the species. Organisms may disperse as spores, eggs, larvae, or adults.

Food chain / food web - All the interactions of predators and prey within an ecosystem, describing how energy passes from one organism to another.

Producer - Any organism which brings energy into an ecosystem from inorganic sources. Plants are producers.

Consumer - Any organism which must eat other organisms (living or dead) to get its energy.

Nutrient - Any element or simple compound necessary for the health and survival of an organism. This includes air and water, as well as food.

Carnivore - An animal that eats meat (other animals).

Herbivore - An animal that eats plants.

Omnivore – An animal that will eat anything – plants or other animals.

Predator - Organism which hunts and eats other organisms. This includes both carnivores, which eat animals, and herbivores, which eat plants.

Prey - Organism hunted and eaten by a predator.

Scavenger – An animal that eats dead animals

Photic zone - Region of the ocean through which light penetrates; and the place where photosynthetic marine organisms (plants) live.

Plankton - Tiny, free-floating organisms of the ocean or other aquatic systems. They may be phytoplankton or zooplankton.

Phytoplankton - Tiny, free-floating plants living in water.

Zooplankton - Tiny, free-floating animals in the sea. Unlike phytoplankton, zooplankton cannot produce their own food, and so are consumers.

Student activities

Activity IE-1 : Tide simulator

This simple model shows how the tides work. The very small bulge on the blue 'sea' circle is not noticeable until it covers up part of the land as the model is rotated.

Activity IE-2 : Sharks and rays

A fun, physical game that is good for early on, to see how much (or how little) the group knows. By varying the questions and making them all relate to a specific theme, the game can be used to reinforce the messages of a particular session.

Activity IE-3 : Mapping your seashore

Making a map of the coastline, to see where different types of beach and human activities occur, can be an entirely desk-based exercise, with students finding the information from books, photographs, invited visitors, the internet and other sources. Alternatively, they can walk parts of the coastline and map it as they go along. The group can work as a whole or small groups of students can map different parts – the areas closest to where they live for example. The information can then be collated into a single map, which can be displayed as a poster or mural.

If you do this as a field activity either with the whole group or with small groups working independently in their own time, bear in mind all the usual safety concerns for fieldwork and include this in the activity briefing session.

The purpose of the activity is to teach the students more about the physical environments in which marine life is found. Later activities will build on these foundations by teaching the students more about the different types of animals and plants associated with different types of shore. Students should consider what they can see along the shoreline (rock, sand, mud, mangroves) as well as things they know about just offshore (such as where the reef is close in or distant, deep and shallow areas of lagoon, the presence of any passes or islets).

By also considering human developments and activities, the mapping exercise also highlights the different ways in which people use the coast, and starts to introduce how these activities might affect the habitats and lives of marine plants and animals. This can include discussions of things like how coastal vegetation might have had to be cleared to make way for buildings, agriculture, or aquaculture, and how the waste produced by these activities might make its way into the sea. There may be other related issues, such as coastal erosion threatening buildings – how the sea behaves affects people, as well as the other way around.

Activity IE-4 : Creating a shore profile

As well as looking at the different shores around the coast, it can be interesting to see how a particular shore changes in height between the sea and its landward margin. This simple activity lets the group create a profile of a local shore, using little more than tape measures and measuring poles (which you may need to have made up locally).

Activity IE-5 : The sea - still a mystery

A useful extension to the shore mapping activity (IE-3) is to consider how research is undertaken under the water. Shore mapping may have had its own challenges (such as navigating large areas of mangrove), but land activities remain far simpler than conducting anything similar at sea.

Only in the last century has Man been able to really explore under the sea by SCUBA diving and using submersibles. We know more about space than the deepest parts of the ocean. Marine scientists have to face a whole different set of problems to scientists who study the land.

Explore why the sea is a challenging environment to work in – brainstorm words that sum up why the sea is different (dangerous, wet, inaccessible, corrosive, unpredictable, deep, alien environment etc.) and explain why.

Think about the practicalities of underwater research. A simple task on land can become difficult once you are underwater – something as straightforward as making field notes, for example. Some of the difficulties encountered by marine scientists in carrying out fieldwork include:

Getting to the site

- Weather (rough sea)
- Tides
- Boat transport
- Cold and sea sickness

Underwater

- Breathing
- Depth (a diver can only spend a limited time at depth)
- Waves and currents
- Carrying and using equipment
- Communicating
- Recording observations

In this activity, the students will plan a survey of a coral reef. They should consider what they would do before getting on the boat: the kind of factors that need to be taken into account are safety, manpower, tides and currents, weather, equipment, recording sheets, etc. etc. A marine scientist would find out as much information as she could while still on land, by, for example, studying plans and charts, finding out tide times and checking the weather forecast. If she hadn't been to the site before, she might also talk to local divers and fishermen about what to expect. She might also map the site using sonar equipment to get a picture of the underwater seascape.

The kind of equipment a marine scientist would take on a dive includes:

- Another person to dive with – YOU NEVER DIVE ALONE
- A wetsuit – even in tropical waters, the deeper you go, the colder it is. A suit also protects the diver from cuts and stings
- A SCUBA (Self-Contained Underwater Breathing Apparatus) set – a tank of pressurised air and a regulator (tubes, valves and a mouthpiece) to allow you to breathe from it
- Mask and fins
- A buoyancy device – a life-jacket, which can be inflated and deflated underwater to help the diver go up and down, to reach the right depth
- A weight belt – a diver has to have weights to compensate for the air in his tank and suit
- A slate and pencil for writing notes
- An underwater torch
- An underwater compass to find your way back to the boat
- A tape measure – to set the length of reef you will survey
- A quadrat – a square frame, used to work out how much seaweed or how many animals there are in a particular area
- An underwater camera/video camera
- Sample pots to collect specimens to identify

After the survey she will complete a log of the dive, identify any specimens and write up her results.

Not all underwater research uses divers. Water samples (to test for nutrients or pollution, for example) can be collected from discrete water depths by using a Niskin bottle. This is a tube with a sprung lid on either end that is lowered from the boat. When it is at the required depth, a weight is sent down the rope and causes both lids to snap shut so that the water is contained and does not mix with that from shallower depths on the way up. Sediment samples can be easily taken from soft seabeds using grabs. There are many different designs, which usually involve open jaws or a scoop, which are dropped from the boat and close on contact with the seabed.

Activity IE-6 : Speaking the same language

Divide the group into pairs for this exercise to see if we are 'speaking the same language'. Each pair is given a card with an ecological term and tasked to give a definition and a marine example.

Prepare the students for this activity by discussing the terms in the glossary above.

Activity IE-7 : Using the right language

A useful way to encourage students to practise using scientific terms is to ask them to write a commentary to a short clip of underwater film, using as many ecological terms as possible. Footage can be obtained from the internet or a DVD, or if there is a video camera available, the students could go to the beach and shoot and narrate some film of marine life on the shore.

Activity IE-8 : Introducing ecology quiz

Here are the answers! Don't just tell your students the answers, have them explain them to each other. Get them to make up more questions about the parts of the topic they found most interesting.

1. The gravitational forces of the moon and the sun
2. Spring tides
3. In constrained channels, such as passes in the reef or between the islands
4. Filter feeders
5. Because they need sunlight
6. A 'home' for marine life, the particular place in which a certain community lives
7. The bedrock, anything arriving there from another location (e.g. soil run-off), the strength of waves and tides
8. Specialists
9. Because not many others do, so they have little competition for food and space
10. They can have shell or spines, puff themselves up by taking in water, sacrifice certain body parts, hide or be camouflaged.

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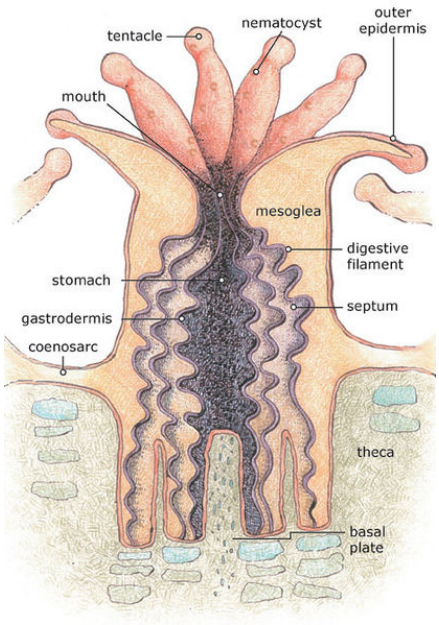
Reefs and Lagoons

Coral reefs are some of the most diverse, exciting and vulnerable marine resources that we have. This section of the education materials is about how reefs form, about the animals and plants that live there and about how we can affect them.

Corals

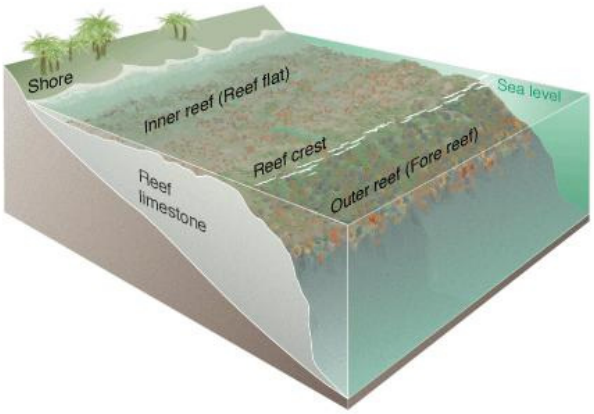
Students often think that coral is simply a kind of rock, but in fact corals are animals. Each is like a tiny anemone-like animal (a "polyp") living inside a hard, rocky skeleton made from calcium carbonate.



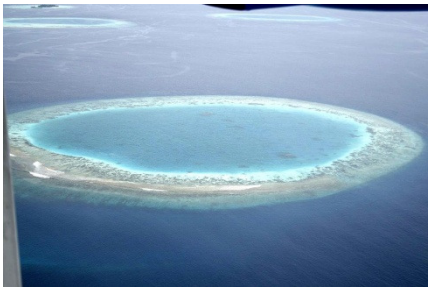
Corals can catch food using tentacles armed with stinging cells. Most also have single-celled symbiotic algae (zooxanthellae) living in them. The algae photosynthesise and produce important nutrients like glucose and amino acids, which are shared with the coral polyp in return for a safe place to live.

Zooxanthellae are very important to corals, but if the environmental conditions become unfavourable (usually too hot) then the algae leave the coral in the phenomenon known as coral bleaching. Since the algae give the polyps most of their colour, bleached corals appear white. Corals can survive bleaching for short periods of time, but unless the zooxanthellae return quickly they will eventually die.

Healthy corals grow upwards and outwards and the skeletal material builds up beneath forming the framework of the reef. Corals may only grow a few millimetres a year, but can ultimately form large structures. Australia's Great Barrier Reef is clearly visible from space, and took around 7000-8000 years to reach that size.



Reefs often act as natural sea defences along tropical coastlines and around islands. The corals grow up to the surface of the water but not above it, so they form an area of shallow water on which ocean waves may break. The area inshore of the barrier is sheltered and calm. Often this includes areas of deeper water known as lagoons. Lagoons are often sandy with additional small patches of coral. They can be an ideal, safe habitat for students to explore at low tide or by snorkelling.



The image to the left shows an atoll – a ring shaped coral reef with a circular, sheltered lagoon on the inside.

As well as corals, reefs include a very wide diversity of different kinds of animals and plants. Reefs are sometimes called the "rainforests of the sea" because of the large numbers of different kinds of organisms which interact with one another in complex food chains and webs.

As well as being beautiful places, coral reefs are important coastal defences, for fisheries and as possible sources of new medicines. They are crucially important and need to be understood and looked after carefully.

The resources in this section of the pack introduce students to the biology of coral reefs and some of these uses and threats.

Animal diversity in reefs and lagoons

There are a great many different types of animals in the lagoon. Scientists use something called the Linnaean System to sort the animals into many different groups, and each group will have smaller groups within it. The largest groups of animals are called **phyla** (singular phylum), each of which includes several **classes**. Within a class, **orders** and **families** group progressive closer relatives. A **genus** is the smallest group, within which are individual **species**.

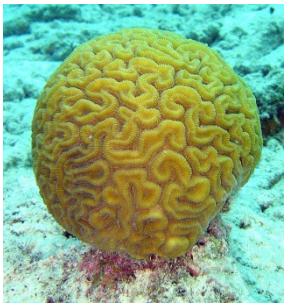
Here we will only cover a small number of the most important phyla and classes which students are likely to come across on reefs or in lagoons.

Phylum Cnidaria

The cnidaria are simple animals with sac-like bodies and tentacles with stinging cells called nematocysts. There are three important classes: the Scyphozoa (jellyfish), the Hydrozoa (Portuguese man o'war and fire corals) and the Anthozoa (corals and sea anemones). The corals are the most striking and arguably the most important animals on the whole reef.

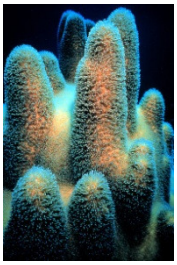
There are hundreds of different types of corals but these can be grouped together into typical growth forms.

Massive corals



In this context massive doesn't necessarily mean huge, although some certainly are. Massive corals have a boulder like growth form. They may be smooth in appearance with very small polyps (*Porites*), have a system of wrinkles or canals along the surface (brain corals like the *Diploria* in the picture on the left) or have large, protruding polyps (*Monastraea*). Massive corals are some of the slowest growing species, only increasing in size by a few millimetres per year. They are often mined as building materials.

Submassive



These are often called pillar corals. They are thick branched and sturdy but not boulder shaped like the massive corals.

Tabulate corals

These are wide, flat corals with narrow bases like this *Acropora*.

Staghorn corals

Staghorn corals are some of the fastest growing species, their branch tips may grow by 10-15 mm per year. They are very fragile and easily broken by trampling or wave action, but the broken fragments often survive and may grow into new colonies.

Plate corals

These corals form thin plates, whorls or sheets. They are often very fragile. This example is a *Montipora* species.

Fire corals

Fire corals are not true corals at all and are more closely related to the Portuguese man o'war than to sea anemones or other corals. They form a smooth, branching, often bright yellow or greenish colony. Fire corals have powerful stinging cells which hurt if you brush against them and leave a burn-like mark for several days.

Phylum Annelida

The annelids are segmented worms. There is only one really important class on corals reefs, the Polychaeta. Other annelids found on land include earthworms (Oligochaeta) and leeches (Hirudinea).

Polychaetes have soft bodies and are eaten by many other animals including fish. To defend themselves some grow in a tube so that only a small part of their body is displayed. Others have brittle, glass-like hairs on their bodies which break off in the skin or mouths of predators. Some even bite, so be careful when handling them!

The feathery structure on the right of this image is a tube worm. Most of the worm is in a tube in the rock, but it has extended feathery tentacles from its head and is using them to filter-feed. It sieves small plankton out of the water for food.

This fire worm has thin, brittle spines which may break off in your hands. Don't handle anything that looks like this, as the spines will sting your skin!

Phylum Arthropoda

Arthropods are some of the most familiar organisms in the reef. The most important class is the Crustacea, which includes crabs, lobsters and prawns but also many small planktonic organisms like copepods and isopods which are important in food chains.

Many crustaceans are important food sources.

Phylum Mollusca

The three classes you are most likely to encounter are the Gastropoda (snail-like organisms), Bivalvia (clams, oysters and other things with a shell in two halves) and the Cephalopods (octopus and squid). The Cephalopods may have a small internal shell or none at all. There are many edible molluscs but also some highly poisonous ones. Do not handle shells such as this cone shell, its sting is very dangerous.

Phylum Echinodermata

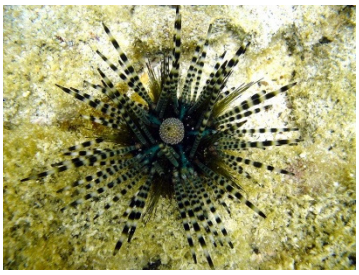
The echinoderms (the name means "spiny skin") are very conspicuous on reefs and in lagoons. There are five classes, three of which you are very likely to encounter in shallow water.

Class Asteroidea - Sea stars or starfish

Typical sea stars have five arms though some have many more. A detached arm with some of the central disk may well be able to regrow into a complete starfish.

Many sea stars are grazers which scrape algae from the rocks. Others are active carnivores and prey on molluscs. The crown of thorns starfish eats corals and sometimes occur in damaging plagues.

Class Echinoidea – Sea urchins



Sea urchins have long spines which can cause painful wounds and many are poisonous.

Most graze algae from the surface of the rocks. They are eaten by some fish, despite the spines.

Class Holothuroidea – Sea cucumbers

Despite the name these are not vegetables, although some are edible, such as the *beche de mer*. Sea cucumbers do not look like typical echinoderms as the spines are very reduced and buried in the skin.

If handled too much, sea cucumbers will eject a mass of sticky threads from their anus. Be careful!

Phylum Vertebrata

These are very familiar animals with internal skeletons and backbones. They include the sharks and rays (Elasmobranchiata), bony fishes (Teleosta) and the marine mammals like whales and dolphins.

Whales and dolphins are not fish but evolved from terrestrial mammals which returned to the sea and became hairless and streamlined. They breathe air. You will notice some other differences too if you look closely; for example, the tail fins of sharks and bony fish are vertical whereas dolphins and whales have horizontal flukes.

Student Activities

RL-1 : Who's who?

This activity introduces the various animals you are most likely to encounter on a trip to the reef or lagoon. Many of them can be seen by walking on a reef flat or in shallow water.

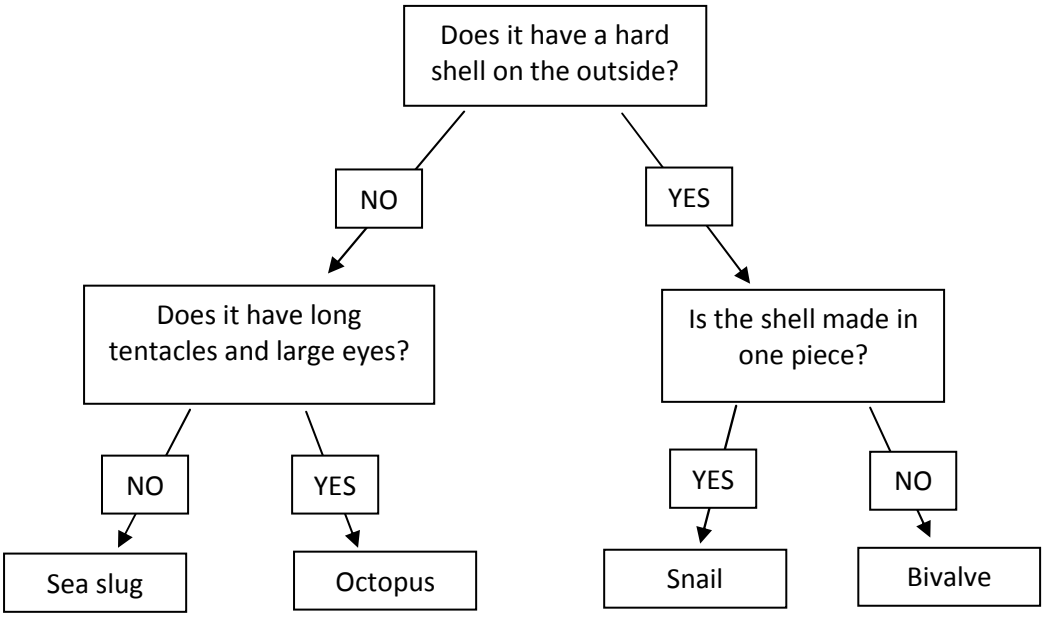
1. Coral (Cnidaria: Anthozoa)
2. Shark (Vertebrata: Elasmobranchia)
3. Dolphin (Vertebrata: Mammalia)
4. Tube worm (Annelida: Polychaeta)
5. Sea snail (Mollusca: Gastropoda)
6. Crab (Arthropoda: Crustacean)
7. Octopus (Mollusca: Cephalopoda)
8. Spiny lobster (Arthropoda : Crustacea)
9. Prawn (Arthropoda: Crustacea)
10. Sea cucumber (Echinodermata: Holothuroidia)
11. Fire worm (Annelida: Polychaeta)
12. Jellyfish (Cnidaria : Scyphozoa)
13. Sea anemone (Cnidaria : Anthozoa)
14. Sea urchin (Echinodermata: Echinoidea)
15. Fish (Vertebrata: Teleostei)
16. Bivalve (Mollusca: Bivalvia)
17. Sea star (Echinodermata: Asteroide

RL-2 : Write a key to marine invertebrates

Reading from left to right the four animals in the pictures are a sea slug (*Aplysia*), a bivalve (*Tridacna*), gastropod (*Conus*) and an octopus.

Encourage your students to design keys to phylum or class level as this will be much easier than species level. Try to have them use characteristics which are unambiguous and which do not change with age or size. Ideally each question ought to eliminate about half of the possibilities, though this will not always be possible. Try to avoid questions at the start which ask about very specific characteristics of one organism. For example "does it have a hard skeleton on the outside?" is a much better question than "does it have long thin antennae with white stripes?".

As an alternative, keys can be written out in a branching diagram, like this…



RL-3 : Food chains and webs

Most organisms eat more than one kind of food and are themselves food for more than one kind of predator. Have your students research their own animal in books or on the internet and find out who it eats and who eats it.

To view a poster produced by the US National Oceanographic and Atmospheric Administration go to http://coralreef.noaa.gov/education/educators/resourcecd/posters/images/iyor_foodweb.jpg This poster is free to download and print out. There are several others at the same location.

Once you have produced your food web, discuss what might happen if one species suddenly disappeared. Who would go hungry? And who might grow in number? What would happen then?

RL-4 : Marine plants and photosynthesis

This is a very simple experiment to show that photosynthesis in plants chemically alters the water, absorbing carbon dioxide and producing oxygen.

By bubbling air from your lungs into the water you add additional carbon dioxide, which dissolves to form carbonic acid. This should cause the bicarbonate indicator to turn yellow.

The plant absorbs the carbon dioxide to make sugars, but only in the sunlight. The indicator should turn back to red or purple as the water becomes less acidic.

The plant doesn't have to be planted in the sediment, which would be very difficult to do! Suitable algae will be found on most rocky shores – choose non-calcareous algae which are soft, easy to get in the bottle and grow fast! You will not need very much in each bottle and if you don't collect very much then don't worry, it will just take slightly longer to get a result.

RL-5 : Pollution in the lagoon

This activity encourages students to adopt a section of beach and then to keep it free of pollution, especially plastic debris. Do plan what you will do with all the collected plastic before you start, otherwise your education centre may start to look like a dump. Some of the collected plastics, especially empty drinks bottles, will come in useful for various experiments. Some plastics can be recycled but this varies from place to place.

It is very likely that each new tide will bring new plastic waste to the beach.

Part of the message of this exercise is that we are all responsible for our rubbish. Hopefully your students will take the message home to their parents that plastics make cheap, useful containers but that we should not just throw them away when we have finished with them.

RL-6 : How long does pollution last?

The "biodegradeometer" makes an excellent wall display for the outside of a building. A square piece of plywood (or similar) can be fixed to a wall fairly easily and then items of waste can be

pinned to it with small nails. Try some of the following: plastic drinks bottles, soft drink cans, shampoo bottles, potato crisp packets, balloons, fruit peels (banana and orange peel last a surprisingly long time) and anything else you can think of. Plastic containers are often marked with the precise plastic they are manufactured from, so try to use a range of different kinds of plastics. Some plastics are now photo- or biodegradable and will break down much more quickly.

RL-7 : Pollution and algal blooms

Tropical waters are normally very clear because they are very low in important nutrients like phosphate and nitrate. Without these mineral ions algae cannot grow, so there are fewer algal cells in the water and fewer zooplankton to feed on them. In cold, fertile waters the sea is full of phytoplankton and zooplankton and so the visibility is poor. If nutrients are added to the water due to man's activities then algae start to grow as algal blooms.

Algal blooms are a bad thing for several reasons. Blooms in the lagoon will block out much of the light needed by corals so their symbiotic algae will be unable to photosynthesise and the corals may die. Some marine algae are toxic to fish or can accumulate in shellfish and be poisonous to humans.

Because lagoons are often sheltered and have limited exchange with the open ocean pollutants tend to remain there rather than being flushed out to sea. This is a problem especially when inhabited islands are surrounded by a lagoon, such as in Rodrigues. Humans add nutrients to the water in a number of different ways. Sewage is very rich in nutrients and is often discharged into lagoons. Agricultural fertilisers may be washed off the land and so can wastes from raising animals. Many detergents contain nutrients like phosphate.

In the experiment you should observe a great deal more algae grows in the bottles with the added fertiliser. It may form a green layer on the inside of the bottle.

RL-8 : Reefs and lagoons quiz

1. Echinoderm means "spiny skin"
2. Sea urchins, sea cucumbers (also brittle stars and sea lilies)
3. They are in the Phylum Arthropoda, Class Crustacea
4. A coral is an animal
5. Photosynthesis
6. All animals are consumers
7. 10,000 tiny fish died to save you (and millions of plankton…)
8. An algal bloom
9. Biodegradeable
10. Check when low tide is, tell someone where you are going, tell them when you will be back, wear sensible footwear, wear sunscreen, wear a hat, take lots of water to drink, don't pick anything up if you don't know what it is, watch where you are walking, don't go into deep water, take a first aid kit and many others!

Marine Education Trust

Sandy Shores

This group of activities is designed to get students thinking about the life on a sandy beach. This is a difficult environment in which to survive and many of the organisms are small or buried in the sand, which can make them hard to see. Students will be amazed by how much is under their feet, particularly on slightly more sheltered beaches.

Everyone likes 'going to the beach'. This is an ideal set of activities to do as part of a fun expedition to a local shore. Some of the activities can be done on the day, some will need materials to be brought back to the classroom and others will require repeat visits.

What is sand?

Sands are formed by erosion of larger pieces of rock. On islands the sand you find on the beach will all be made by the local environment. It may be generated by erosion of coral, sea shells or from the bedrock of the island itself.

Coral and shell sands are made of calcium carbonate, which was used by corals or molluscs to make their skeletons or shells. Calcium carbonate sand may also be formed from fossilised reefs, or limestone. These sands may be formed by wave erosion but also through the activity of grazing organisms. Parrotfish in particular are important in the generation of coral sand. The fish scrape algae from dead corals, or even bite live coral. The coral is then ground up in the fish's digestive system before being passed out with the faeces. If you snorkel or dive close to parrotfish you will often see little plumes of new sand being ejected from the fish's rear end. Other grazing organisms like sea urchins are also important for this process. Calcium carbonate sands can be easily identified; the sand is usually very white and it may contain small recognizable pieces of shell or coral. It also dissolves in acid producing bubbles of carbon dioxide gas.

What kind of sand is formed from the bedrock depends on local geology. Islands formed during volcanic activity from ocean floor crust, like Mauritius, are mainly basalt which forms dark coloured sands. The Seychelles are formed from continental crust and are mainly granite, which forms light yellow quartz sand. Beach sand in these places may be a mixture of sand from different sources.

How do beaches form?

Sand will be washed along the shore until it arrives in a place where the waves and currents are too gentle to keep it suspended in the water. It will then settle out and accumulate. This will usually be in bays that are a little more sheltered than the surrounding headlands. Sand will often build up inside sheltered lagoons and form small sandy islands called **cays**.

Coastal areas with sand or mud are places where sediments have built up, and are **accreting** shores. Conversely, those areas of coast where rock is being broken down and swept away are **eroding** shores. Of course, if conditions change temporarily (a sudden storm) or permanently (a change in ocean currents for example) then sand may rapidly disappear from an area. Sedimentation patterns

may also change due to changes in land use, for example deforestation or irrigation can result in increased runoff of sediments from the land.

Sand on a beach may be very uniform or it could be made up from grains of different sizes. High energy shores will tend to have larger grain sizes, as the smallest particles settle slowly and are washed away. The most sheltered bays with the least wave action will have finer-grained sands and muds. Sea grasses and mangroves will also help to stabilise the sand and allow small, fine particles to settle out and not be washed away. Sand low on the shore is exposed to less wave action than higher up, so also tends to have more small grains. Generally speaking fine grain sands will be more interesting from a biological point of view, as they contain more food material and a greater range of organisms than clean, coarse sands.

Student activities

Activity SS-1 : How sandy is your beach?

The idea of this activity is for students to have fun whilst finding out a bit more about sand. They will probably never have thought very much about it before.

In the experiment any large sand grains will sink rapidly to the bottom of the bottle or measuring cylinder, whereas smaller, light particles will take much longer to settle and will end up on the top. Organic matter (**detritus**) is fragments of dead organisms and will also be found mixed into some sands. This provides an important food source for small organisms living in the sand, including the worms in the "How many worms" activity. The detritus will usually settle right on the top of the column of sand and give a band of varying thickness. It will be much thicker in silty, muddy sands than in clean sands from beaches with strong wave action.

Adding acid to calcium carbonate sand will result in some fizzing and the production of carbon dioxide gas. Quartz sands from igneous rock (basalt or granite) will not do this.

Activity SS-2 : How many worms?

Another fun outdoor activity that introduces some important principles in field ecology is random sampling and use of quadrats. It will be most fun when the number of worms is high, so make sure you use a beach where you know there will be lots! Fairly sheltered beaches with fine sand are best. You also need to time the activity to coincide with low tide.

Try to get students to relate the number of worms to the environmental conditions. Get them to explain why some beaches are better for worms than others.

Your students will naturally want to see what the worms look like, so it is a good idea to take a garden spade with you so you can dig some up. Be prepared to dig quite a deep hole!

Activity SS-3 : Bird diary

Infaunal worms and other invertebrates feed on detritus and bacteria in the sand so are more common in finer sands with a high detritus content. Because they are relatively large they are a very attractive food source to fish (when the tide is high) and birds (at low tide). There are a wide variety of different birds which can be seen hunting for shellfish at low tide and many of them have beaks which are specially adapted for probing in the sand.

The "Bird Diary" activity is best carried out by a small group of more dedicated students, possibly slightly older ones. It will require considerable patience to do well!

This project provides a lot of opportunities for students to do more research on their own, perhaps on the internet, to find out more about the birds that they see. Things to consider are whether their beak is a special shape to catch particular prey, or where the birds go in the times of the year when you don't see them.

Activity SS-4 : Between the grains – Meiofauna

This is a great activity if you have access to powerful magnifying glasses or, ideally, microscopes. Meiofauna are organisms which are almost too small to be seen with the naked eye, generally between about 0.5mm and 0.05mm in size. They live in between the sand grains; many are detritivores but there are also some carnivorous ones. Examples of meiofauna include nematode worms and crustaceans. It might be possible to see them without a microscope, but you won't really be able to tell what they are.

If you use a small, weighed sample of sand, say 5g, and count all the animals in it then it might be possible to estimate the total number of meiofauna on the beach. It will be a very large number!

In order to see meiofauna is it important that the sand samples come from an area of wet sand and that you don't allow it to dry out. Take a few spoonfuls of sand from near the low tide mark and keep them in a sealed plastic bag or airtight container. Keep this cool and view the animals as soon as you can. Alternatively you could take some 70% alcohol or methylated spirit and add about one teaspoon of sand per 10ml alcohol in a small bottle. Remember that dead animals will be harder to spot and much less interesting to look at than live ones!

Activity SS-5 : Beachcomber collage

An art based project for students of all ages and abilities. With just a few extra materials, scissors, glue, paper and string you can transform whatever they find on the beach into all sorts of pictures, models and mobiles.

Many of the sandy shore activities require the tide to be out, but the best beachcombing is often done at the top of the shore along the strand line, so the materials can be collected at almost any state of the tide. Plastic litter can be used but it is more interesting to try and identify more natural materials. You can expect to find shells, driftwood, skeletons of crabs and heart urchins, feathers, pieces of coral, seeds such as coconuts or sea beans, pumice stone etc. Get your students to talk

about what they find and to say what it is and where it came from. Is it something local, or has it travelled a long way?

Encourage the students to create large pictures which tell stories about the marine environment and use these to decorate your classroom. They could include details of food chains or the life styles of particular animals. Smaller pictures and models can be taken home. Encourage them to explain them to their parents!

Activity SS-6 : Catching crabs

This is another great use for discarded plastic drinks bottles. Small invertebrates, especially crustaceans such as ghost or fiddler crabs, will easily be caught in pitfall traps above the high tide mark. The whole trap can easily be removed from the sand in order to observe the catch. The traps are best set out in the evening, somewhere where they will not be disturbed, and checked the following morning. There is no need to use bait, the smell could attract scavengers such as dogs who might try and eat the animals you have caught!

There are a number of different species of crabs which may be caught in this way, including fiddler crabs (genus *Uca*) and ghost crabs (genus *Ocypode*). *Grapsus,* the 'sally lightfoot' crab, is more common in rocky areas but may also be caught. Crabs are generally easy to identify using keys or guides and your students will enjoy learning the differences between them.

Try pitfall traps in different areas to see if there is variation in the species that you catch. If you see differences, have your students try to explain why that is. Consider aspects of the environment like shelter, vegetation and humidity.

Many land crabs build burrows. Try placing pitfall traps in areas where there are burrows so that you can catch and identify the crabs responsible.

Activity SS-7 : Sandy shores quiz

Here are the answers! Don't just tell your students the answers, have them explain them to each other. Get them to make up more questions about the parts of the sandy shore they found most interesting.

1. Sandy shores are **accreting** shores.
2. Animals that live buried in the sand are called **infauna**.
3. The process by which animals stir up sand and sediments is **bioturbation**.
4. The smallest animals that are just visible to the naked eye are collectively known as **meiofauna**.
5. The patch at the top of the beach where debris washes up is the **strand line**.
6. Large worms are most common at the **bottom** of the beach.
7. There are lots of different seabirds! Allow any ones they might see locally.
8. The mineral that makes up coral sand is **calcium carbonate** but quartz sand is **silica.**
9. The smallest sand grains sink the **slowest**.
10. **True!** A lot of coral sand is parrot fish poo!

Marine Education Trust

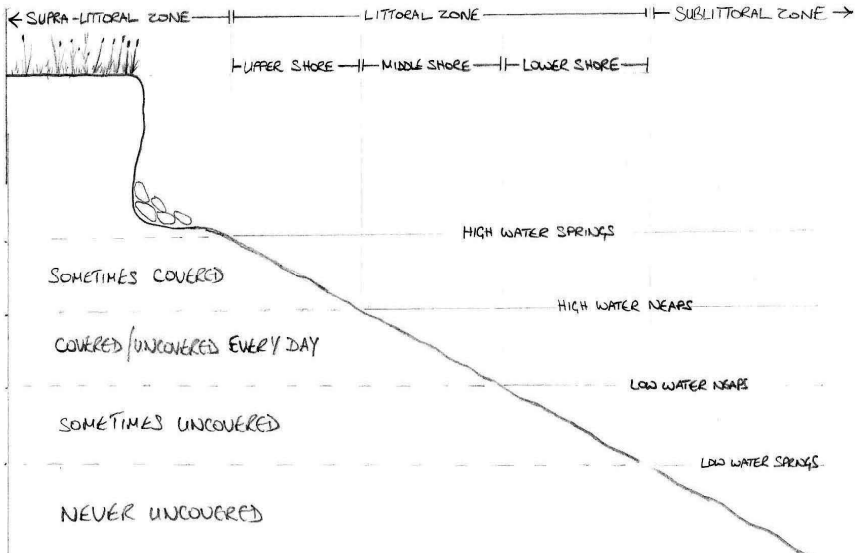
On the Rocks

Rocky shores are a harsh environment for marine animals, as they cannot burrow and wait for the tide to come back in, as is possible for creatures on sandy or muddy beaches. Tropical rocky shores are most commonly made from soft, grey limestone or smooth, black basalt. Basalt is an **igneous** rock, formed when molten lava flows from erupting volcanoes quickly cooled and solidified on contact with the air. It is this rapid cooling process that gives basalt its glassy appearance. Its sometimes bubbly texture results from air having been trapped inside. Basalt is the most abundant volcanic rock in the Earth's crust, and makes up most of the ocean floor.

Limestone is a **sedimentary** rock, which, on tropical shores, has a predominantly biological origin. It was formed when the shells and skeletons of once-living organisms were transformed into rock by the weight of other material piled up on top of them. Limestone is more easily eroded than basalt, and can be undercut into overhangs by the regular action of even gentle waves.

Zonation

One feature that is particularly apparent on rocky shores is the way in which animals and plants occupy different levels (or zones) on the shore, depending on how long they are exposed by the changing height of the tide. The difference between high and low water is much greater on spring tides than on neaps, and the heights of spring and neap tides also change throughout the year. As a result, different parts of the beach are subject to different amounts of exposure. The highest parts of the shore are rarely covered by water, whilst the lowest are rarely exposed to the air.



The upper shore is home to the hardiest animals, while those that can only withstand a short time out of water are found closest to the sea. Predator/prey relationships are also a factor in where marine life is found. On rocky shores, the grazing of algae by sea snails has an impact on where on the seaweeds can grow. Wave exposure can be a factor too. If the rocks take the full force of the incoming waves, species unable to tolerate the strong wave action have to live higher up the shore.

Adaptations

Marine animals and plants are, by definition, underwater organisms, so how do they survive being out of the water and why are some of them better at it than others?

When the tide has gone out, marine animals will move into the most comfortable conditions they can find, which are cool and damp places like under boulders, in crevices, or, if nothing better is available, the shady side of a rock. Many of them cannot, however, move all that far or all that fast, and getting to these cool spots is not without risk, as they are exposed to both the sun and predators when moving around in the open.

Plants cannot move anywhere, and must face the full force of the sun and wind. Plants have two ways of tolerating intertidal conditions. Thick stems and **fronds** (leaves) with a low ratio of surface area to volume help reduce water loss in the first place. Alternatively (or additionally) the plant may be tolerant to drying out – some species can survive the loss of as much as 80% of the water in their tissues. Upper shore species are so well adapted to living between the tides that they actually photosynthesise at a greater rate when exposed than when submerged.

Molluscs use their shells for protection against the elements. This ability to trap water inside their closed shells keeps them cool and moist and well adapted for shoreline living. Mussels and other **bivalves** will tightly close their paired, hinged shells, while limpets latch firmly to the rock, and other **gastropods** (sea snails) have a hard plate (called an **operculum**) which they can use to seal their shells. Barnacles, which are **crustaceans**, close their shells in a similar way, and hermit crabs pull themselves as far into their shells as they can.

Even some fish manage to survive between the tides, although only if they can find somewhere very damp such as the back of a cave or the tiniest puddle. Rockskipper blennies can breathe through their skin as well as their gills, so as long as they can stay moist they can survive out of water. Blennies generally prefer larger rock pools, which are often a refuge for many creatures when the tide has gone out. They are not entirely comfortable habitats, however, as the heat of the sun causes the water to evaporate, and the pools can become very salty.

Other soft bodied, mobile animals like worms, brittlestars, and sea cucumbers take refuge in the cool and damp beneath rocks. This shade is essential for their survival, as they are very vulnerable to drying out, so if you turn over rocks in search of marine life, you must put them back as you found them when you have finished.

Student activities

Activity OR-1 : Tide in! Tide out!

A fun game to illustrate the problems marine animals face when the tide goes out, and the different ways they adapt to the situation.

Activity OR-2 : Seashore detectives

This activity allows the students to discover and learn about different species that interest them.

As with all fieldwork, student safety is of paramount concern. For this exercise, it is particularly important to warn them against handling any animals that they find, but instead just to observe. It should be stressed that cone shells are poisonous, and that fire worms have an unpleasant sting. A 'no handling' policy also reduces disturbance to the animals, and students should be reminded to return any rocks or boulders that they overturn while searching for species.

Activity OR-3 : Art with algae

Drying algae is a fun way to create original art, but it does also serve a useful purpose, as herbarium collections show where and when species were found and can show what has been lost.

Activity OR-4 : On the rocks quiz

1. Black, smooth and glassy.
2. Igneous.
3. By the rapid cooling of lava from volcanoes.
4. Soft, light grey in colour.
5. Sedimentary.
6. From the shells and skeletons of marine animals that are compressed into rock by the pressure of material building up on top of them.
7. The length of time they are exposed to the air by the changing tide level; the strength of wave action; the presence of predators.
8. By sealing their shells. Bivalves close the two halves firmly together, limpets latch tightly to the rock and sea snails seal the open end of their shells with the operculum.
9. Worm, brittlestar, sea cucumber, crab, hermit crab, sea snail.
10. True (providing they stay damp).

Marine Education Trust

Marvellous Mangroves

This group of activities is designed to get students thinking about the importance of mangroves for both wildlife and people. It is an opportunity to change their perception of mangroves as unpleasant places that should simply be cut down to provide timber or space to build ponds for farming prawns.

Mangroves don't grow just anywhere – only on sheltered tropical coastlines from 25^0N to 25^0S, so much of the world doesn't have them! They are very valuable resources which should be conserved.

What are Mangroves?

Mangroves are a group of salt-tolerant trees that can grow on sediments with high salinity. These sediments are often anaerobic (they lack oxygen) and sometimes acidic. Mangroves are found along muddy estuaries, sheltered lagoons, bays and inlets. They are always found in sheltered coastal settings, between the tides. In regions where mangroves are extensive they show **zonation**, with different species occurring at different heights up the shore. If the area is small, or the mangroves have been replanted, there will only be a few species and no zonation.

Mangrove biodiversity

There are ten species of mangrove in the Western Indian Ocean, the most important of which are *Avicennia, Bruguiera, Rhizophora* and *Sonneratia*.

Mangroves forests, or **mangals**, are rich in biodiversity and are home to many plant and animal species. The height of the trees means the roots are in salt water but the tops are never immersed. Marine species live in the lower parts, and terrestrial species in the branches.

The marine species include those that burrow in the hard substrate of the roots, those in and on the mud and those that take advantage of the safe, sheltered environment and plentiful food supply. Examples include:

- **Crabs** are a common sight living in numerous holes in the mud around mangroves. The male fiddler crabs have one large claw, which they use to attract females and to defend their territory. You can sometimes see broken-off claws as a result of a fight over a female! When the tide is in these crabs hide in their holes. Crab burrows are very important for a number of other animals as hiding places or places to feed or breed. Burrows also allow oxygenated water to enter the mud.
- **Shrimps** burrow into the mud. Often these shrimps will live in burrows with small fish called gobies (Gobidae, below). They clean out the burrow while the fish keeps watch for predators.
- **Barnacles**. You can find these attached to the roots of mangrove trees. They use their modified legs to filter microalgae and detritus from the water.

- **Fish** e.g. gobies (family Gobidae). These are common in the mud around mangroves. They can hop around on the mud, or walk on their fins and can spend some time out of water. Mullet (Mullidae) are also common in mangroves, the young fish seek shelter amongst mangrove roots. Many other juvenile fish will feed and seek shelter amongst mangroves.
- **Reptiles and Mammals.** Both green and hawksbill turtles are occasionally found in mangroves. Dugong (sea cows) and crocodiles are also found in the mangroves in some places.
- **Birds.** Mangroves are the roosting, feeding and nesting sites for many water birds and migratory birds. Herons will feed on snails, bivalves or worms in this habitat. There are many other types of birds that will visit to feed or to roost in the trees at night. Some of these birds may be migratory, such as plover and spoonbills, and may rely on these habitats as a stop-over on their long journeys. If mangroves are destroyed, some birds may become locally extinct.
- **Bats.** Fruit bats roost in mangroves during the day, as the thick growth is hard for predators to get through. These bats are very important as they act as pollinators and disperse seeds. It may be possible to watch the bats flying out of the mangroves at dusk.

Adaptations of mangroves

Intertidal mudflats are a poor habitat for plants. The soil is often waterlogged, salty and low in oxygen. The soft sediment provides little support for large trees, which are at risk of toppling over.

The roots of plants need oxygen for respiration but this is lacking in fine, silty sediments. Many mangroves have 'knees' in their roots – sharp bends which stick out of the sediment into the air. Others have vertical 'pencil roots' or **pneumatophores**. Knee roots and pneumatophores will be covered by water for much of the time but can obtain oxygen from the air when the tide is out.

Mangroves also deal with salt in different ways. Some are able to keep the salt out of their roots, others store it in their leaves or, like *Avicennia*, secrete crystals of salt from the leaves.

The roots of mangroves are not deep, but shallow and spread out. Much of the mass of the tree is below ground, so they sit upright in the soft silt instead of toppling over.

Mangroves and Man

Mangroves are important to people in a number of ways:

- They act as a barrier between land and sea – they catch and accumulate sediments, which are washed off the land, and the pollutants that accompany it. This prevents the sediment from spilling out across and damaging coral reefs.
- They provide safe nurseries for many of the fish we eat and support small-scale harvesting of shrimps and crabs.

- In the future mangroves may be important sources of new medicines. There are still many chemicals to be discovered, due to the high biodiversity. If this is lost, we do not know what potential beneficial drugs we may be losing
- They are used for dyes. On some islands, a red dye was traditionally extracted from mangrove trees for household floors.
- They can be interesting places for tourists to visit, especially because of the birdlife they attract. In some tourist areas boardwalks have been put down to make nature trails.
- They can be used for fuel (fresh or charcoal) or termite-resistant timber (often poles). Depending on the species, they may be used for building materials, to make fish traps, boat masts and bed legs.
- They produce tannins which can be used to tan leather.

Threats to mangroves

Mangroves are often perceived as 'waste-ground' by decision-makers and increasingly threatened by reclamation for development or conversion into land for agriculture, aquaculture and other development activities. Although mangroves contribute to the economies of countries in many different ways, other forms of land-use such as reclamation or conversion to housing, hotels, industrial sites, or aquaculture seemingly bring greater profits in the short term.

Mangroves trap debris and are often used as rubbish dumps by people. They also trap excess nutrients and toxins through their natural filtering processes. This improves water quality of rivers and seas but pollutants accumulate in the sediments of the mangrove.

Visiting a Mangrove

Everyone likes 'going to the beach' but might, perhaps, feel differently about visiting a muddy mangrove.

Involve the students in producing a checklist of things to do in preparation for the visit:

- Check the tides
- Check local conditions e.g. how deep is the mud?
- Check whether it has got the facilities we might need e.g. bus stopping area, emergency telephone
- Check whether the areas we want to study are safe and accessible
- Visit the most suitable sites and check access
- Arrange transport
- Make sure the students are dressed suitably: old trainers/waterproof boots, old clothes, shirt/hat to protect from the sun
- Take a First Aid kit and some insect repellent
- Take the equipment you need for the study

Student activities

This set of activities can be done in the classroom (or at home) or as part of a fun expedition to a local mangrove. Some of the activities can be done on the day, some will need materials to be brought back to the classroom and others will require repeat visits.

Activity MA-1 : What do mangroves mean to you?

"Dirty", "muddy", "smelly", "dangerous", "full of nasty creatures", "rubbish dumps". This is how people often think of mangroves. True, they are muddy, but they are important to us and to wildlife and full of surprises!

List the students' perceptions of mangroves on the left-hand side of a black/white board or flipchart. Counter them with the positive advantages of mangroves and discuss. Which list is longest?

This activity could be repeated at the end of the module. Have the students' perceptions changed?

At the end of the module, the students might like to design a poster to raise awareness of the importance of and threats to mangroves.

Activity MA-2 : A visit to a mangrove

Get the students to use the key to identify the mangrove trees. Reddish trees with dramatic curving roots will generally be *Rhizophora*, ones with lots of bendy pencil roots are *Avicennia.* Check the bottom of the leaves for salt crystals!

Look around under the roots for crabs, on the roots for barnacles and bivalves and up in the trees for birds. Keep a list of everything seen.

Activity MA-3 : Mangrove food webs

This activity will help the students to understand the inter-relationships between the plants and animals of the mangrove forest. To be able to create the mangrove food web, the students have to find out who eats whom. They can do this from books or the internet although a lot of it will be common sense. If they play the game with the string first then their cards can be used to make a wall display afterwards.

When discussing food chains, get the students to consider how and why energy is lost as you move along the chain. Organisms use up some of the food they eat in order to move around so only some of what they eat is left over for growth. Some energy passes through their bodies in undigested food and is lost as faeces, and of course not all food is eaten in the first place.

Marine food chains rarely have more than 4-5 trophic levels.

Activity MA-4 : Mangroves in the past

This activity encourages students to ask their parents and grandparents about historical uses of mangroves. This can also tell us whether mangroves ever existed in places where there are no records or surviving trees. There is a good list of uses of mangroves in the section "Mangroves and Man" near the beginning of this document.

Encourage students to consider which uses of mangroves are sustainable and which are not.

Activity MA-5 : Mangroves role play

Before you start, discuss the importance of mangroves to wildlife and people. Encourage the students to suggest ways mangroves have been used in the past and are used now. It will help if they have completed the "Mangroves in the past" activity.

Set the scenario that a hotel/industrial/airport development is proposed for the area and the mangrove will have to be felled and reclaimed. Try to think of a realistic development that could really be proposed for your area.

The students must represent the local community and have various different interests. A list of possible participants is given on the student sheet but you could change the list or add more people, depending on how many students you have: restaurant owners, shop keepers, bird watchers, wildlife enthusiasts, students, are possible alternatives. Give the students some time to think about how they would feel and what key points they would like to make in the discussion that follows.

Some students will have to make arguments they don't themselves believe in. By explaining someone else's point of view they will understand the debate more clearly!

Activity MA-6 : Mangroves quiz

1. Mangroves grow in sheltered, silty locations on tropical coastlines.
2. A mangrove forest is called a mangal.
3. Buttress roots prop up mangroves and stop them falling over.
4. Mangrove roots get oxygen using knee roots or pneumatophores (pencil roots).
5. There are 10 species of mangrove in the Indian Ocean region.
6. *Avicennia* has salt crystals on the bottom of its leaves.
7. Possible uses of mangroves include timber, firewood, making charcoal, making medicines, tanning leather, making dyes or for tourism.
8. False – mangroves are excellent nursery areas for young fish.
9. False – mangroves are being cleared for timber, reclaimed land and for aquaculture ponds.
10. False – Australia's national plant is the Golden Wattle (*Acacia pycnantha*) – definitely not a mangrove!

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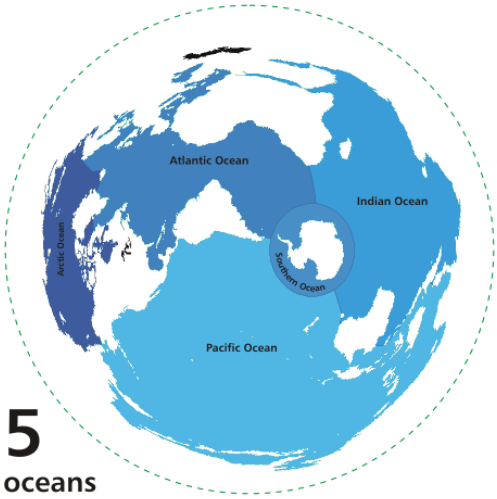
The Open Ocean

Oceans and seas cover approximately two thirds of the Earth's surface. It should be called Planet Ocean, rather than Planet Earth! The oceans are all joined together – a ship could sail around the World without touching land.



There are five oceans in the World: Arctic, Pacific, Atlantic, Indian, Southern and Arctic.

- The Pacific Ocean is the largest and the deepest ocean, covering over one third of the globe. It could cover every continent and is larger than the Atlantic and the Indian oceans (the next largest oceans) put together.
- About 97% of the world's water lies in the oceans.
- Mount Everest, the highest mountain in the world (8,848 meters) would sink without trace in the deepest part of the ocean.
- We could not survive without the oceans – they spread warmth around the globe, like a huge radiator, and recycle rain (ocean water evaporates, condenses over land, falls as rain or snow and returns to the sea). They also provide us with resources such as fish, oil, gas and aggregates.

Your Own Indian Ocean

The Indian Ocean lies south of Asia and between Africa and Australia. It is the third largest ocean in the world, covering 20% of the earth's total ocean cover. The deepest place in the Indian Ocean is the Java trench, which is 7,450m deep. Compare this to the depths of 40m that recreational divers will normally reach. However, in general it has relatively shallow waters, characterised by a profusion of coral islands and atolls. The islands include Sri Lanka, Madagascar, Seychelles, Comoros, the Maldives, the Chagos Islands, Socotra and the Mascarene Islands (Mauritius, Reunion, and Rodrigues).

How does the sea work?

The sea does not stay still like a pond – it is constantly moving. On the surface, waves are formed by wind, blowing over the surface of the water. The rise and fall of the tides causes currents called **tidal streams**, which are often mapped on charts to help sailors work out where they are and plan their voyages. Water may also move vertically, when waters of different temperatures or different salinities meet.

As well as causing waves, the wind can also create currents. These may be local and short term, or vast regional phenomena. The trade winds that blow from high pressure subtropical regions towards the low pressure areas of the Equator, form the basis of huge ocean circulation patterns. The currents of the western Indian Ocean are influenced by the trade winds and also by the monsoons which occur in the northern part of the Indian Ocean. The continental land masses of Africa and Asia, as well as the islands and submerged mountain ranges, also affect the current patterns.

Most currents move horizontally, but they can also cause vertical water movement. One example is **upwelling**, which occurs when deep ocean water is drawn up into the surface layers. Surface currents take water away from the coastline and water flows up from deeper layers to replace it. This deep water, which may flow up from depths of several thousand metres, has a rich supply of nutrients which have been lost from the upper layers, but are not used at depth because lack of light prevents photosynthesis. Once these nutrients are recycled into the surface waters, they become part of the food chain. The southern monsoon season causes upwelling off the coasts of Somalia and the Arabian peninsula, creating a highly productive fishery during the winter months.

Plankton – tiny drifters

Drifting at the mercy of the currents are the **plankton**: tiny plants and animals that can only be seen through a microscope, but which are so numerous that several thousand can be found in a single litre of seawater.

The oceans can be extremely productive. This is especially true of shallow or coastal waters where wave action and the tides stir up nutrients from the sea floor and rivers and streams carry runoff from the land into the ocean. Productive ocean waters are murky and green due to the growth of tiny microscopic algae known as **phytoplankton**, which have two important roles: they feed the food web and, through the uptake of carbon dioxide, have a vital role in regulating global climate.

Deep tropical oceans are not green, but blue. The water is very low in nutrients and very little phytoplankton can grow, so the water is very clear. Although they look beautiful, clear blue oceans are the deserts of the sea with very little food production compared to coastal waters. Islands and atolls are like oases in these deserts – small areas where nutrients are recycled and food produced.

A step up in the food chain is the **zooplankton** (tiny animals) in which the larval stages of many larger marine species (from barnacles and molluscs to octopus, crabs and fish) can be found. Some animals, the **holoplankton**, remain microscopic for the duration of their lifespan, and many members of this group are tiny crustaceans called **copepods**. Despite being so small, some copepods are voracious predators, with long, comb-like arms to help them catch other zooplankton.

Zooplankton are also eaten by small fish or even by great whales. Productive ocean waters therefore support important fisheries which Man can exploit, but because production is limited so is the amount of food we can take from the sea. Very often we take too much and the result is the collapse of fish populations and the disruption of ocean ecosystems.

Whales and Dolphins

Like all mammals, whales and dolphins have to breathe air. The give-away 'blow' or 'spout' (sometimes several metres high) of large whales, as they surface to breathe, is the best means of locating the animals in the open sea. From land, the most common whale sightings are humpback whales. They communicate by complex songs, which can be heard tens of kilometres away.

Eight species of dolphins, including bottlenose, common, striped, spotted and spinner dolphins inhabit the Indian Ocean. They are masters of in-water and aerial acrobatics and enjoy bow-riding on the wave created at the front of a boat as it moves through the water. Some dolphins even hitch a ride on the bow-waves of large whales!

Human threats to whales and dolphins include commercial whaling – Japan and Norway still hunt whales commercially. There is a whale sanctuary in the Indian Ocean in which no whaling is allowed. Whales and dolphins are also caught accidentally in fishing nets. A dolphin can only hold its breath for a few minutes and will soon drown if trapped in a net. This is a particular problem when old fishing nets, sometimes many kilometres long, are thrown away into the sea. Technological solutions to this problem are being sought , such as sonic 'pingers' that warn the animals of the presence of the net. Alternative, "dolphin friendly", fishing methods include hook and line fishing and tuna caught in this way can be sold to European customers for a higher price than net-caught fish.

There is some good news for whales too, however. Pressure from whaling is much lower than it used to be and as wildlife tourism develops whales and dolphins have become a valuable commodity. Tourists will pay high prices to go on whale watching trips so it is very much in the interest of coastal communities to protect their whales.

Turtles

Turtles can hold their breath for much longer than marine mammals, but this does not stop them being trapped and drowned in fishing nets. A green turtle can stay submerged on a single breath for up to five hours by slowing its metabolism so far that its heart will beat only once every nine minutes. A person's heart, by comparison, will beat about 700 times in the same period. Turtles can also sleep underwater.

Turtles come ashore to lay their eggs. This also makes turtle populations vulnerable: people catch the females or take the eggs , and the nesting beaches may be at risk from coastal development. Even if the eggs are left undisturbed by people, baby turtles have only a one in one thousand chance of surviving to adulthood. After hatching, they have to cross the open beach to reach the sea, and predatory crabs and seabirds lie in wait for them. Even the sea itself is not a sanctuary, as most that have made it across the beach will then be eaten by fish. Biology does its best to help the turtles, as all the eggs in a brood hatch together and they tend to emerge at night so that darkness and safety in numbers enhance the baby turtles' chances of survival.

Very little is known about young turtles. They are open ocean animals, and often associate with rafts of *Sargassum* seaweed or other floating debris as this gives them some protection from predators. Other animals, on which the turtles feed, are also attracted to these mid-ocean refuges. After about five years at sea, turtles return to more coastal waters. Individual turtles may stay in a particular area for many years, but are also thought to travel thousands of miles between different feeding grounds. Turtles mature at about 30 years old, and will return to the beaches on which they were born to lay their own eggs. How they find their way back after years at sea remains a mystery, although one theory proposes that the arrangement of the Earth's magnetic field at the nesting site becomes imprinted on the turtle during incubation or just after hatching.

Sharks and Rays

Sharks have been swimming in the oceans for 300 million years. There are around 360 different species, and many of these live around coral reef areas. They are the top predators and feed on the larger fish, rays and octopus, being superbly adapted to catching their prey with their fast swimming speed and well developed senses.

Sharks and rays are grouped together, and separated from other fish, because their skeleton is made of cartilage, not bone. Their reproductive biology is also different; unlike bony fish they do not produce large quantities of eggs that are left to float free in the seawater. The fertilised eggs of some species look like leathery pouches. These **mermaid's purses**, as they are often known, are usually attached to seaweed by means of the strong, curled fibres found on the corners of the pouch.

Sharks have a very tough skin, which is covered in sharp spines called **denticles**. They also, notoriously, have very sharp teeth. The teeth grow in continuous rows, with new ones moving forward as the old ones wear out. Their jaws can close with as much pressure as a chopping axe: 3 tonnes per square centimetre. Many of the terrifying images and stories of shark attacks have created an unreasonable fear of this creature. Only a few kinds of shark are dangerous, and attacks on people are rare. One group of swimmers that attracts particular attention from sharks are spearfishermen, who carry dead fish. The smell of blood has a strong attraction for sharks, and they can detect it from 400m away.

Not all sharks are voracious predators, however. At 12m long, the whale shark is the largest of all sharks, but it feeds on zooplankton and small fish such as sardines and anchovies. Whale sharks swim through the water with their mouths wide open, using sieve-like structures attached to their gills to filter out kilos of their tiny prey. Whale sharks are believed to be highly migratory, travelling throughout tropical seas and even straying into temperate waters, but they often congregate near reefs a few days after the coral has spawned. It is thought that the huge volume of coral eggs attracts plankton and small fish, which in turn attract the whale sharks.

Student activities

Activity OO-1 : Making waves

Ocean waves are responsible for many features of our coasts. They erode rock and deposit sand on beaches. Storms can move enormous quantities of sand so that beaches can disappear overnight. Coral reefs act as important breakwaters, reducing the effect of waves and creating sheltered areas where different species live compared with exposed coasts.

In this activity you can model the effect of ocean waves on a model coastline. Try to build up trains of steady, rhythmic waves and you should notice the clay or mud gradually eroding and a sandy "beach" forming. The result will be different if you build a "reef" in front of the shore to break the waves. Prepare the model before the session as the mud takes a few hours in the sun to dry!

Activity OO-2 : Tiny drifters

In this activity you can make a plankton net and catch some of these tiny drifters. Even if you don't have a powerful microscope you should be able to see zooplankton with a simple magnifying glass. Most of them will be tiny crustaceans and you may be able to see their swimming movements. If you do have access to microscopes then your students will be thrilled by the diversity of organisms.

Activity OO-3 : Whale tales

In the Whale Tales activity your students are encouraged to interview as many older people as possible to try and find out whether whale sightings were more common in the past or whether now is a good time to try and see them. It is a great opportunity to involve older family members. If any of them have especially good stories, why not invite them to come and talk about their experiences the next time you see your students?

Activity OO-4 : Open ocean quiz

1. Two thirds (or, more precisely, 71%)
2. 97%
3. The Java Trench
4. Upwelling
5. Low
6. Zooplankton
7. Eight
8. True
9. False (it's made of cartilage)
10. True

Marine Education Trust

Conservation Concerns

Harvesting the marine environment

People use the sea's resources for a wide variety of purposes. Mostly this is for food, but a whole range of products, from fertiliser to industrial chemicals to rope to medicine is also manufactured from marine plants and animals. Dead marine organisms, particularly large gastropod shells and echinoderm tests, are collected as curios and for decoration, and live ones are caught for aquaria. Marine life is also valuable in its natural habitat – people try to catch it for sport, or snorkel or dive just to see it, all of which generates high levels of income as part of the huge coastal tourism industry. Companies extracting sea salt, sand and gravel for building, metals, precious stones, and oil and gas can also generate vast amounts of money.

Directed fisheries land all sorts of species, including gastropods, bivalves, octopus, squid, sea cucumbers, urchins, crabs, lobsters, and prawns as well as sharks and fish. The size of fisheries varies almost as much as the range of species caught. Small-scale fisheries in lagoon and reef areas involve collecting by hand as well as the use of small nets, hand-held lines and fish traps. In the open ocean, the fisheries that target large pelagic fish and large shoals of smaller species can use nets that are many kilometres long and lines with hundreds of hooks.

The wealth of the ocean was long considered inexhaustible and so exploitation has taken place on a massive scale. The extremely damaging effects of this free-for-all are now widely known, as populations of marine species are declining and disappearing throughout the world's oceans.

The impacts of fisheries

One example of the devastating effects of fisheries is the case of turtles and whales. Turtle meat and eggs are eaten and many different ornamental products are made from their shells. Whale meat is eaten too, the oil from their blubber was used for lamps, soap, margarine and as a lubricant, and there was a diverse range of uses for the flexible, resilient baleen used by the whales to strain plankton from seawater. Demand for all these products was such that the fisheries had a catastrophic impact on whale and turtle populations, and some species were hunted to total extinction. Right now, the demand for fish and shark products is having a similar effect on the numbers of these species too.

The main problems caused by fisheries are taking too many animals, or catching them too small before they have had time to breed. The impacts go beyond the target species, however, as most fishing gears are indiscriminate and will collect everything in their path. This bycatch of species caught unintentionally often exceeds the landings of the actual target of the fishery. Where there is no market for the bycatch, it will be dumped back in the sea, although the animals are usually dead or dying by then. Fishing gears like traps which are dropped on the reef, or those that trawl or dredge the seabed can also devastate marine habitats, turning them from diverse, complex environments that support many species into featureless deserts.

The use of aquaculture to farm marine animals and plants can be seen as a way to reduce the pressure on wild stocks, but irresponsible aquaculture programmes can actually cause greater numbers of wild animals to be landed (when obtaining females for brood stock), destroy habitats (when building ponds), spread diseases to wild populations, and pollute waters with waste products.

Other threats to marine life

Marine species and habitats are also threatened by other human activities. Coastal development for housing, tourism or infrastructure can destroy mangroves and turtle nesting beaches and can affect shallow habitats like seagrass beds. With coastal building and habitation comes increased consumption of water, fuel and food and the generation of waste, which create their own environmental problems. Tourism can be a particularly damaging development in this regard, as the levels of consumption and waste tend to be higher than for ordinary residential developments of the same size.

Digging up mineral resources stirs up the seabed and affects light and sediment levels, with implications for the species living there. It can also have impacts far beyond the area in which the extraction takes place, by affecting current regimes and changing the patterns of erosion and sedimentation. Pollution is also a problem for marine life, both in terms of poisoning by chemicals and oil and because plastic litter is eaten, by turtles and whales particularly, which can be fatal for them as they cannot digest it.

Endangered Species

The continued vulnerability of marine species is highlighted by the Red List produced by the International Union for the Conservation of Nature (IUCN). It details the conservation status of different species according to the number of mature animals remaining, rate of population decline, and size of the species' geographical range.

Within the western Indian Ocean region, three species of whale are endangered as are four species of turtle (two of them critically endangered). Two hammerhead shark and three other shark species are endangered (two are critically endangered) and there are four species of endangered fish, including the critically endangered bluefin tuna.

Endangered means that the animal (or plant) has a "very high" risk of becoming extinct in the wild. For critically endangered species, this risk rises to "extremely high". If the list is expanded to include those species that are just vulnerable, with merely a "high" risk of becoming extinct, then the number threatened species becomes considerably larger, and the range of species on the list widens.

Some conservation solutions

At an international level, the Convention on Trade in Endangered Species of Wild Flora and Fauna (CITES) aims to protect threatened plant and animal species by regulating cross-border trade.

Trade in species named in Appendix I of CITES is permitted only in the most exceptional circumstances, and this particular list includes whales and turtles. Appendix II allows restricted trade, and species on this list include sharks, fish, coral, molluscs and even sea cucumbers species.

Other steps have also been taken to protect specific groups of animals. The International Whaling Commission banned all commercial whale hunting after 1986, although some countries (notably Norway and Japan) still hunt. There are two whale sanctuaries (in the Indian and Southern Oceans) in which no whaling is allowed.

Most issues, however, and their solutions, are local. The impacts of fisheries can be reduced if controls are put in place, and typical management measures include catch limits, net size restrictions, closed seasons and the issue of licences to control the number of people involved in the fishery. Technological solutions to prevent bycatch are also being explored, which include exclusion devices that allow turtles to escape from shrimp trawls.

Tourism can help protect the animals from illegal directed fishing, because whale watching and scuba diving can make a vital contribution to local economies, and so the animals become more valuable alive than fished.

Probably the most promising strategy for conserving the marine environment and improving the sustainability of fisheries is the establishment of marine reserves. These are protected areas within which activities that remove marine life or damage habitats are prohibited. As a result, habitats and populations flourish within the reserve, and eggs, larvae and adults of commercial species spill over into surrounding areas, improving fisheries.

Climate change

The ocean does not escape the impacts of climate change. Sea level rise is more of a threat to people on low-lying islands like the Maldives than it is to most marine species. There is, however, a risk to coastal ecosystems like mangroves, which may get squeezed out if barriers such as roads and buildings prevent their retreat landwards away from rising sea levels.

Of much more serious concern is the rising sea temperature and the more frequent occurrences of coral bleaching. As coral is both a species and a habitat, its loss has wide implications for many other creatures.

Perhaps the largest threat to the marine environment is **ocean acidification**. This is caused by increasing levels of carbon dioxide dissolving from the atmosphere into seawater, which causes the water to become more acidic. The hard body parts of marine animals are made of calcium carbonate, but in more acid conditions there is less carbonate available, so they cannot grow their skeletons and shells. This again affects corals and the ecosystem reliant on the reef habitat. It is also a threat to the phytoplankton at the bottom of the food chain, and therefore to the entire web of marine life.

A rapid reduction in carbon dioxide emissions is of the highest priority for marine conservation.

Student activities

Activity CC-1 : Fisheries survey

Discuss declining fish populations, and the effects of over-fishing on the environment. One of the best ways to find out how your local fisheries have changed over the years is to talk with a range of fishermen about their past and present catches.

When the students have finished their interviews, encourage them to learn more about the ecology of the fish mentioned – is there any change in the type of fish caught? It is common for the large predators to have disappeared from catches, and to have been replaced by the lower herbivores, as the former group grow more slowly and mature later, making their populations more vulnerable to overharvesting than species like rabbitfish. Similarly, fishers may have to travel to other areas to find fish stocks, or land smaller catches for the same length of time spent fishing. These are also signs of an over-exploited fishery.

The fishermen may have incidental comments about sightings of sharks and turtles, or of how development has affected the coastal environment.

Activity CC-2 : Marine Protected Area role play

The scenario described on the student sheet is a fun way to get students discussing the issues of resource management and conservation, and to get them to see these issues from different perspectives. After discussing conservation issues and marine protected areas, outline the situation on the fictitious island of Lamorelle.

Below are descriptions of 17 different characters who could be present at the meeting. These can be varied according to student numbers or a specific local situation. It may be useful to reproduce the character descriptions on individual cards for the students.

Diana - Facilitator (Group manager)
Your role is to manage the group and ensure all voices are heard. You need to ensure that your views are neutral. You should write a summary of what is being said on the board so that the participants in the meeting can see them.

Eric - Local marine conservation group
You are the head of the Lamorelle Marine Conservation Society, an active and knowledgeable group. LMCS has been working with schoolchildren to raise awareness and has been carrying out research into fish stocks. Your work has been successful and many more people are aware of the damage that has been done to corals and the loss of fish stocks. You are particularly keen to ensure that there is a network of marine reserves. Tourism is a good thing, as long as no water-skiing is allowed. Sea-cucumber collection should not be allowed. You are neutral about seaweed farming.

Dr Jan de Oosteweger - International conservation group
You are the East Africa representative for the World Nature Fund and are attending this meeting to provide expertise and possibly funding to encourage more marine reserves. As an outside group,

your opinion is resented but your money brings influence. Your money can go towards retraining of fishermen to become reserve rangers.

Donald - Seine net fisherman

You have eight children and are well respected in the community. You have been fishing the lagoon for many years and have noticed that catches are getting smaller. You do not want more hotels since other hotels have damaged the coral in the lagoon and water skiers have scared away the fish. You have heard that marine reserves can be a good thing, but it will take many years before the effects are noticed. How will you make money in the short term?

John the Poacher - Illegal fisherman

You do not care about the health of the lagoon, as long as you can catch a few fish and earn some money. You catch fish at night and often use poisons as well. You often pay the fisheries guards if they catch you. If there are marine reserves you will certainly try and catch the bigger fish that you will find there and you hope that these marine reserves will be close to your house.

Madame Oursin - Octopus fisherwoman

You are a mother of four young children with a lazy husband. You have very little money and survive on rice, beans and what you catch in the lagoon. You walk out at low tide to catch octopus with all your friends and neighbours. Unfortunately you damage all the coral and delicate habitats, but that has not even occurred to you. You are prepared to do any jobs for money such as work in hotels or seaweed farms.

Dr Vera Locke – Fisheries scientist

You are an experienced and reputable marine biologist. You have been assessing the condition of the fisheries and the lagoon for the last 15 years. However, your work is poorly valued locally and few people take notice of what you have been saying.

Mr Matt Spott - Consultant

You are a foreign consultant who is very good at writing very thick and professional reports with a minimum of work and effort. You do not have a clear grasp of the issues and are happy to write a report with a conclusion that suits the highest bidder.

Mr Ah Chen Chuan - Seaweed farming company

You represent a seaweed farming company that has interests around the region. The lagoon is a good place to grow seaweed, but you would have to introduce a new species. The effects of this cannot be predicted. You are also unsure about whether you can make enough money, and may need some subsidies to start the business. Obviously your farms would take away areas of lagoon and not allow fishing. You will employ a few people, but on low wages.

Mrs Grand-Argent - Funder

You are the head of an international funding agency and have a multi-million dollar budget. The objectives of your organisation are to help promote sustainable economies, protect the environment and promote the role and value of women. You are keen to use this opportunity and are prepared to use your funds to support projects and influence decisions.

Benoit La Plonge - Diving boat operator

You and your wife run a small dive business and have developed some regular clients from Europe. Your business relies on a healthy marine ecosystem. If there are no fish or corals to see then you will have no clients. Many tourists come to Lamorelle for the diving and your profession is valued. However, many people think that the money you earn isn't shared and fishermen are jealous of your fancy boat and engines. You have few friends amongst the others in the group, but they know you bring many people to help the tourist economy.

Mr Chue Wan – Sea cucumber collection company

You are manager for a small company that has been set up to collect, dry and export sea cucumbers to the Far East. Sea cucumbers fetch a high price in China, but most stocks around South East Asia have been fished out. Buyers have now set up business in Lamorelle and there is pressure to start fishing the stocks. However the conservation groups are saying that sea cucumbers are important for the ecology of the lagoon. Your company has money and is only interested in the short term profits.

Thierry Chateau - Small hotel owner

You currently run a small and successful guest house. You have raised some capital to build some bungalows near the sea. As a local owner the money will stay within the island, and your bungalows have a lower environmental impact than typical beach hotels. Your clients prefer to come and experience real island life and are relatively environmentally aware. You hope to have the same beach as the other international hotel project, and are well connected even though you don't have enough money for payments to officials.

Rocco Forty - Hotel developer

You want to develop a new beach hotel. You will be creating many new local jobs, but mostly as waiters, cleaners and other low-paid positions. You would also like to start water-skiing in the lagoon. You will try and do as little as possible to treat sewage and pollution from the hotel unless you are forced. The disturbance and pollution will have a bad effect on the fisheries. However, you do have a lot of money and that is very attractive in the short term for helping to make progress.

Jacques Sirac - Corrupt official

You are a Government worker with little interest or motivation. You are lazy and obstructive. However, you are very happy to help any members of your family; or for that matter anyone who is prepared to pay for you to obstruct or promote an idea.

Henri Accord - Honest official

You are a hardworking and keen young official who is keen to impress. However, you are a bit naïve and easily persuaded. You will support whichever idea sounds best. You also have children who have been attending the Lamorelle marine conservation society education programme and they have been telling you how important the marine environment is. Therefore you are likely to side with initiatives which are working towards good protection of the lagoon.

Monsieur LeChef - Island Chief

You have ultimate power over the proceedings, but are obviously sensitive to the political implications of what is decided. Fishermen are obviously the most numerous amongst the electorate, but have very little effect on the economy. You believe that the future lies in tourism, but it is vital that it does not have a negative effect on the environment.

Activity CC-3 : Endangered species poster

To prepare for this activity, discuss with the students the reasons why animals become endangered, and the attempts that are made to protect them. As well as reinforcing these messages, the purpose of this exercise is to encourage them to undertake independent research. A poster is a fairly traditional approach, but, if the facilities are available, the students could present the information they discover in different ways, such as by designing a webpage.

Activity CC-4 : Foods from the sea

The biggest pressure on marine life comes from our desire to eat it, and fisheries remain the central issue in marine conservation. This activity looks at the range of seafood people consume, and also at how patterns of consumption might have changed in the recent past.

Activity CC-5 : Conservation concerns quiz

1. Fertiliser, industrial chemicals, rope, medicine, curios, building aggregates, metals, precious stones, oil and gas
2. Gastropods, bivalves, octopus, squid, sea cucumbers, urchins, crabs, lobsters, and prawns as well as sharks and fish (and any specific animals caught locally)
3. This may be basket trap, seine net, line, or harpoon techniques or gathering by hand/diving, or any other specific local method
4. Animals unintentionally caught in a fishery for another species
5. Catching too many animals, catching them too small/young (before they have bred), damage to habitats from bottom fishing gear
6. Taking wild females for brood stock; clearing coastal habitats to build ponds; spreading diseases to wild populations; pollution from waste
7. Whale watching, diving, snorkelling and other wildlife-focused activities bring in large amounts of revenue, making live animals more valuable than dead ones
8. Coastal habitats may be cleared for building; more water, fuel and food is consumed than in comparable residential buildings; more waste is produced
9. Bluefin
10. Coral bleaching and ocean acidification