Children's Perception of the Environment

A Teacher's Toolkit for Investigating Coastal and Marine Ecosystems in Asia

Vineeta Hoon, Hemal Kanvinde and Gaya Sriskanthan

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A collaboration between
IUCN (International Union for Conservation of Nature), Coastal Oceans Research and Development in the Indian Ocean (CORDIO) and the Centre for Action Research on Environment Science and Society (CARESS)

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Photographs: Learning about ecosystem connections by playing the web of life game, at Minicoy Island, UT of Lakshadweep India; mangrove field trip in Havelock, Andaman Islands; diorama of a turtle; coral feeding game, Minicoy Island, UT of Lakshadweep India; kayaking in the mangroves, Andaman Islands (all photos by V. Hoon).
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Preface

The coastal and marine environment is of vital importance and represents a huge proportion of the Earth's surface, with oceans covering over 70 per cent of our planet. Almost half of the world's human population lives in coastal areas, and there are more than 40 island nations around the globe. However, while remaining vitally important for human wellbeing, coastal and marine areas are threatened by human activities, both on land and in the water. The deteriorating environmental conditions of oceans and coasts are a matter of grave concern to a vast array of communities dependent on them for their livelihoods. World leaders have agreed on specific actions for conservation and sustainable use of oceans and coasts, including Chapter 17 of Agenda 21 that was adopted at the Earth Summit in Rio de Janeiro in 1992, and the Plan of Implementation adopted at the World Summit on Sustainable Development (WSSD) held in Johannesburg in 2002. In order to implement the various agreements and action plans, it is essential to involve the stakeholders concerned through education and communication.

A survey carried out in 2003 with schoolchildren in grades 5 to 9 in India (ages 10-15 years), showed that while the children knew about coral reefs and had seen documentaries on the National Geographic and Discovery television channels, they did not know that coral reefs existed in their own country. Although children in the Union Territory of Lakshadweep (also known as the Coral Islands) understood that the coral reef protected their islands and were able to list the threats to the reef, they could not articulate the importance of the various species that made up the unique biodiversity related to coral reef ecosystems. The children in Minicoy (the only island in the island territory with mangroves) did not know the function of mangroves. They also held the traditional occupations of coconut climbers and subsistence fishermen in low esteem and did not know or understand the importance of the survival skills of the older generation.

Schools in Asia follow national syllabi that often ignore the richness of the coastal and marine environments and local traditions. Therefore, children from areas with important coastal and marine ecosystems, such as coral reefs and mangroves, rarely understand the value of the rich diversity around them. This is one of the reasons why the notifications of environment and forestry ministries are disregarded and conflicts arise in Marine and Coastal Protected Areas (MCPAs). Awareness and understanding of the depletion of natural resources and the efforts needed to mitigate this problem have to be instilled at an early age. We need to focus on how children perceive and relate to their local environment and how they think about their ecological footprints. The average Asian school child, while familiar with the concept of wildlife sanctuaries and protected forest reserves, remains unfamiliar with the concept of MCPAs.

The Asian tsunami of 2004 wreaked havoc in the lives of coastal dwellers of Asia. Many lives were affected, especially in Aceh province of Indonesia as well as in Sri Lanka, the Andaman and Nicobar Islands, Maldives and along the Tamil Nadu coast of India. The tsunami highlighted the importance of ecosystem services as well as the local importance of coastal and marine ecosystems to people all over Asia and the rest of the world.

The goal of this Teacher's Toolkit is to help promote environmental stewardship and increase awareness of marine and coastal ecosystems among schoolchildren in Asia through the use of creative, investigative approaches. Investigative approaches allow schools to make the local environment relevant and interesting to children in coastal communities, and help to reinforce the need for wise and sustainable management of our coastal and marine resources. These activities can contribute to strategies that promote interactions and understanding between coastal resource managers and local communities, which is essential for successful resource management.

This Toolkit is intended for use by teachers in formal education institutes in coastal areas across South Asia and Indonesia, and is produced in Bahasa Indonesia, Bengali, Dhivehi, English, Hindi, Malayalam, Sinhala and Tamil. While the Toolkit targets children in elementary and middle schools, the activities are equally relevant to creating awareness among a broader range of target groups, for example, early school leavers, women and the public. We hope that the Toolkit will be used to stimulate creative learning, enthusiasm and stewardship with regard to coastal and marine ecosystems in the Asian region.

Vineeta Hoon, Hemal Kanvinde and Gaya Sriskanthan

1. Introduction

1.1. Goals and objectives of this Toolkit

The goal of the Children's Perception of the Environment Toolkit is to help children living in coastal and island environments in Asia to become responsible stewards of the environment through a better understanding of coastal and marine ecosystems. The Toolkit also seeks to improve understanding of how coastal and marine ecosystems can be managed in order to create a more sustainable human economy. The Toolkit supports the efforts of teachers to do this through the provision of up-to-date information on important coastal and marine ecosystems as well as by suggesting practical hands-on activities that allow students to explore and understand their local ecosystems and the issues affecting them. The teachers are provided with a framework for teaching local history and ecology in a way that complements science and social studies in line with the national school syllabus.

Local environmental investigations take learning outside the classroom and into the real world. Through carefully planned investigations, students can learn and apply key concepts in ecology, economics and natural resource management, and the connections between these different areas. They can also unleash their creativity and improve communication skills through language and arts while identifying and solving real problems. Learning becomes relevant and concrete, rather than abstract and theoretical. The students take ownership of their studies and make significant progress towards the goal of becoming life-long learners.

Some of the coastal and marine issues covered in the Toolkit are already discussed in the curricula of other subjects such as science, geography and agriculture. However, their coverage in standard textbooks is either very limited or too detailed and specialised, with less emphasis on interactive learning. Therefore, this Toolkit can be used individually or together with other available information on the topics concerned to complement curriculum objectives of different subjects.

Learning as well as participating in field visits to areas of ecological significance and meeting local knowledgeable persons, especially people who derive or supplement their livelihoods by collecting resources from those areas, encourages each participant to value nature as well as the knowledge and skills of their own people. They are also able to see their place in the greater environment rather than just within their small world of home and school.

The activities will assist teachers to make changes in their students' attitudes towards the coastal and marine ecosystems most relevant and close to them, and to make learning about these ecosystems an enjoyable experience. While the target audience of this toolkit is teachers and students of primary and secondary schools (ages 10-15 years) in the Asian region, we found the activities used in the Toolkit to be equally useful in teaching ecosystem concepts to adults; it can be used by anyone who has an interest in basic environmental education, whether it is within a formal school, by children's clubs or societies, or by interested parents at home. Whether your school or locality is in an urban or rural area, located on the coast or an island, you can use your local environment to engage students in active learning, promote scientific thinking and understanding, and integrate other key learning areas in a relevant, real-world context.

Overall objectives of this Toolkit

The overall objective of the Toolkit is to introduce concepts regarding the biological diversity and ecological dynamics of coastal and marine ecosystems, and how human society is linked to them, by encouraging students to:

- Think about how various organisms are ecologically connected;
- Consider the role and impact of humans in coastal and marine ecosystems; and
- Discuss how people could have a positive impact on these ecosystems and how some of the issues affecting coastal and marine ecosystems in Asia could be tackled.

Key concepts

- Coastal and marine organisms are not only linked through the food web – there are many other ways species interact and depend on one another.
- People are part of coastal and marine ecosystems as they use them for many purposes, thus having direct impacts on the ecosystems as well as being impacted on by them.
- There are many ways that people can reduce or reverse their impacts on coastal and marine ecosystems.

1.2. Using this Toolkit

This Toolkit provides a framework to assist you and your students as you embark on an exciting journey of discovery. Based on principles of action research and problem-based learning, it includes:

- Suggestions for ways to design studies that look at ecosystems, economics and conservation;
- Background information material on coastal and marine ecosystems;
- Guidance on simple field data collection techniques and exploratory activities;
- Supplementary classroom activities that introduce or explore key concepts;
- Guidance on presenting findings;
- Guidance on creative expression; and
- References for additional Internet and print resources.

Teachers can use the background information as technical guidance on current thinking on the ecology, economics and management of coastal and marine ecosystems, and utilise the activities in exploring these concepts with the students. The nature of Action Research and problem-based learning means that every activity will take a unique form, depending on specific circumstances such as the location of your school, the interests of your students and the local issues relevant and unique to your location/country. For example, the Asian tsunami of 2004 and other natural events such as cyclones have wreaked havoc on the lives of millions of coastal dwellers in the region. A common starting point is often learning about the natural defences provided by ecological systems such as mangroves, beaches and coral reefs in the local context.

Teachers are free to decide how they wish to incorporate and disseminate the information provided, and can use it in conjunction with any existing syllabus material. They are encouraged to develop their own individual presentation style, and to modify the teaching and learning strategies as they see fit in accordance with their situation and the experience of their students.

1.3. Action Research approach

The Toolkit is based on an Action Research and learning approach. Action Research is a process in which students learn by identifying, researching, and solving problems that are relevant to them. Unlike traditional teaching, which focuses on transmission of information from teacher to learner, Action Research gives the student more control of the learning process. It is basically a circular process of observation, action and reflection. The sections below show the main steps for implementing an Action Research approach. Figure 1.1 gives an overview of the Action Research framework.

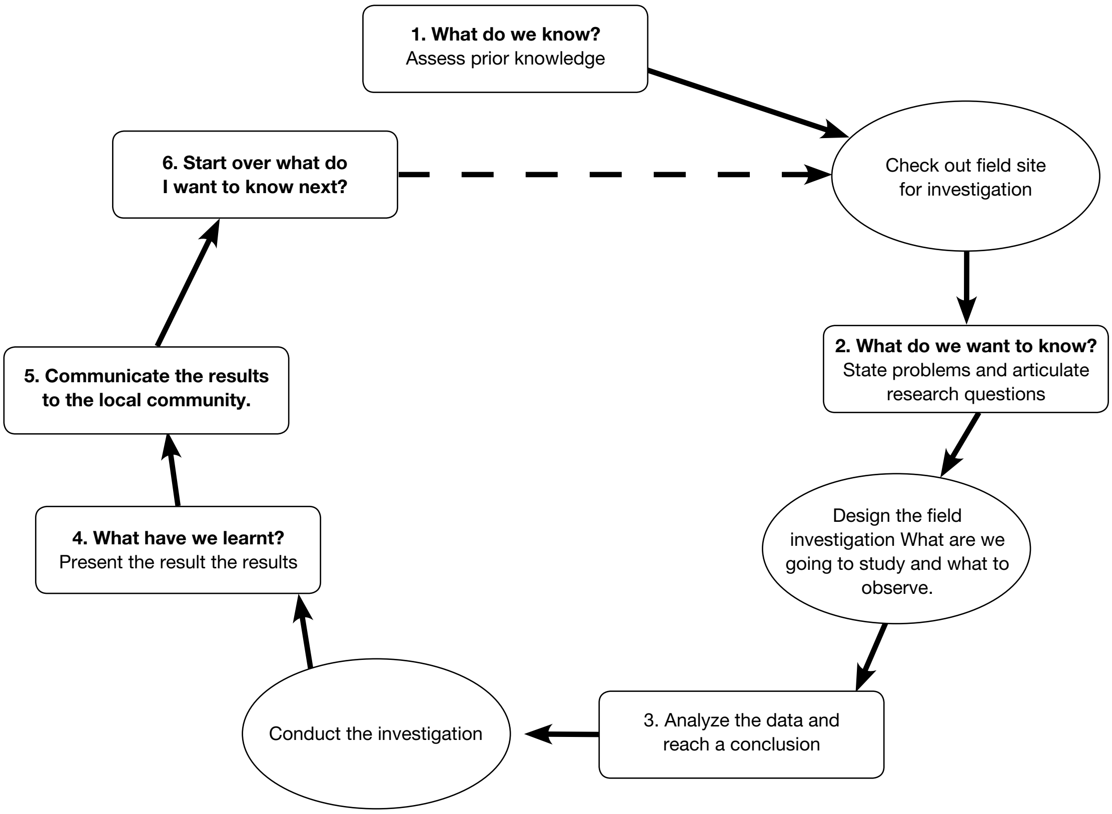

Figure 1.1. The Action Research framework at a glance

Steps 1 and 2: Planning the investigation

What do we know?

All students enter the classroom with certain ideas and beliefs about the world around them. These ideas and beliefs are rooted in the child's life experience and are often subconscious, very firmly entrenched and difficult to change. At the start, it is important to assess what the child already knows or thinks about the subject to be studied. This is the time for only listening and not correcting any misconceptions that the child may have. It also helps to plan your lesson or activity to the appropriate level.

What do we want to know?

Plan your field investigation and decide on your research questions. What do we want to know? For example, you may want to know (a) about various adaptations that plants and animals have developed in order to survive in a habitat, (b) what services are provided by an ecosystem, or (c) how local livelihoods (economies) depend on the resources provided by an ecosystem. How do the people interact with this environment? What is the human impact on this ecosystem? Are the activities sustainable? Are people providing any feedback towards the management of the ecosystem? What can we do to restore a degraded ecosystem?

Step 3: Conducting the investigation

The general pattern for conducting an holistic investigation of coastal and marine ecosystems, through looking at ecological, economic and locally relevant aspects, is described below (the methodologies or activities used to carry out an investigation will depend on the local situation and the preference of the teachers and students):

- Choose a suitable area/sample site for study – e.g., coral reef, lagoon, seashore, seagrass beds, salt marshes, mangroves, estuaries or an urban coastal stretch;
- Choose a method for exploring the physical environment. This could include ecological sampling techniques such as the use of transects or quadrats for a biodiversity inventory or rapid ecosystem damage assessment, or simply a guided trip through an ecosystem;
- Observe the adaptations that plants and animals have developed to survive;
- Observe how people use and interact with the ecosystem, how it is being impacted on and how it is being managed;

- Meet and hold discussions with local people – this could include, for example, how they perceive the status of the ecosystem, how they use it (what resources, species methods etc.) and how it has changed over time/since their childhood;
- Note all observations and make detailed recordings.

Step 4: What have we learnt?

In order to assist the students to process and understand what they have learnt, the findings can be presented in a number of different ways. Through using varied methods, the teacher will build the students' skills as well as create increasing interest in the subject matter.

Presenting the findings scientifically

Information can be processed in a "scientific" manner in order to help students understand technical ideas as well as build their skills in scientific understanding and analysis. Techniques that can be used include:

- Listing plants/animals seen and classifying them by group in order to understand the roles of different animals in the ecosystem, e.g., primary producers and consumers, and functional or trophic groups such as herbivores, carnivores, detritivores etc.;
- Noting any specific adaptations to the environment. For example, for first-time visitors to mangroves adaptations such as propagules, stilt roots, breathing roots and knee roots may catch the students' interest;
- Explaining the role of plants and animals within the ecosystem, based on classification into functional groups. Who does what? Describe special associations;
- Describing the role of abiotic and physical factors such as sunlight, weather, water, tides and soil;
- Studying human impact and dependency – both positive and negative;
- Comparing what the economic system and ecological system have in common, and discussing how they are linked.

Presenting the findings creatively

Use a mix of creative methods to allow the students to express their findings and new knowledge. Techniques that can be used include:

- Poem and essay writing;
- Drawing and painting;
- Preparing a power point presentation; and
- Dioramas or models of coastal and marine animals or plants.

Step 5: Communicating results to the local community

There are a number of activities that can allow students to communicate their findings with the broader community, thus creating more interest in the subject matter and making it relevant to their lives outside school. Techniques that can be used include:

- Celebrating an environment day or officially recognised event (e.g., World Environment Day is officially celebrated on 5 June every year) and "international years" that are designated for different species or ecosystems (e.g., 2008 was the International Year of the Reef).
- Developing an environmental awareness exhibition where children's outputs can be displayed to the public. Children can stand by their exhibits and explain key learning to the public.
- Children can act as nature guides and take the people through marked trails in a habitat and explain ecosystem services.
- Developing short plays (5-20 minutes) based on their key learning, or holding a fancy dress event in which each participating child comes dressed as a coastal or marine organism and explains its importance.
- A walking or cycle rally on key learning, using slogans and placards.

Step 6: Starting over – what do we want to know next?

Action Research is a learning cycle that should be continuous. As coastal and marine ecosystems are not static, and because many of the children's findings may represent one stage of continuous monitoring, interest can be sustained over time. Changes as well as new topics or ideas, can be explored, and the learning cycle begins again.

2. Exploring coastal and marine ecosystems

This section introduces the main coastal and marine ecosystems, animals and plants as well as basic ecological concepts regarding the organisation and complexity of ecosystems.

Specific objectives

After completing this section the student will be able to:

1. Distinguish between different coastal and marine ecosystems such as coral reefs, mangroves, salt marshes, sandy, muddy and rocky shores, and urban coastlines;
2. List and explain adaptations and inter-relationships found in coastal and marine ecosystems (e.g., symbiosis in corals);
3. Explain the diversity of life in different coastal and marine ecosystems and how they are inter-related;
4. Explain the web of life, food chains, trophic pyramids and the role of energy in powering ecosystems.

2.1. Introduction to coastal and marine ecosystems

More than 70 per cent of the Earth's surface is covered by ocean. While this sounds like a huge amount it is actually only 0.05 km^2 of ocean for every man, woman and child alive today. Since most of us only come in contact with the sea area along coastlines this is particularly important for human society; however, this area is also most affected by human activities.

Figure 2.1 shows the coastal and ocean zones, including coastal dunes, hard and soft coasts (i.e., rocky shores and beaches), the continental shelf with mangroves, seagrass beds and coral reefs, the continental shelf and open ocean. Each zone has its own specific characteristics with special organisms adapted to living there.

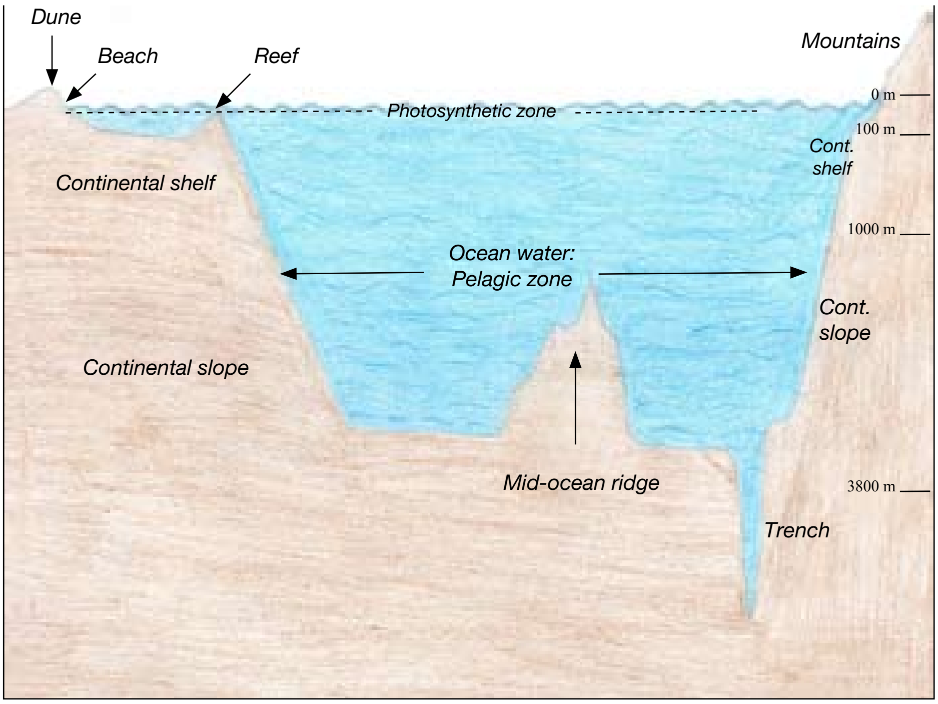

Figure 2.1. Coastal and ocean zones

Source: *Adapted from H. T. Odum, 1988; redrawn by B. Begum.*

Coastal and marine ecosystems are not isolated, but connected with each other and also with land ecosystems. The direct links include rivers bringing freshwater, dissolved nutrients and sediments from inland regions to the coastal seas, and the evaporation of seawater providing moisture in the atmosphere that eventually falls inland as rain. There are also many interconnections within coastal and marine ecosystems. For example, many fish use mangrove forests for breeding, but spend their adult lives in coral reef ecosystems. This has led to the development of complex food webs involving many plants and animals that exist in coastal and marine ecosystems. (An example of a coral reef food web is given in figure 2.6).

Millions of people across Asia depend on coastal and marine resources for food and jobs. Coastal and marine ecosystems have long offered opportunities for livelihoods and recreation, including fishing and other harvesting. During the past two decades in particular, coastal tourism has become an important commercial activity for many Asian countries. In addition, coastal and marine ecosystems support a range of essential natural processes, such as regulating global weather patterns and global warming, stabilising shorelines and acting as a barrier or natural defence against extreme events, thereby making them very important to our survival.

This chapter reviews coastal marine ecosystems, where they are found and how they work.

2.2. Coral reefs

What are coral reefs?

Most corals are attached to the seabed and many people think they are plants or rocks. But corals are actually animals that are responsible for building the reef. Corals can therefore be regarded as the architects and construction engineers of the sea. They provide homes and living space for the hundreds of thousands, if not millions, of other species that live in coral reef ecosystems.

Tiny coral individuals, called polyps (figure 2.2), usually living as colonies comprising many thousand individuals, have worked generation after generation for millennia to construct coral reefs and islands. The polyps are soft-bodied animals that produce a hard calcium carbonate-based material with which they surround themselves for protection. The basic structure of a coral reef consists of this "exoskeleton", which remains after they die. New polyps grow over the skeletons, and over many decades the reefs grow in size, with the thin layer on the top of the reef remaining alive with corals and other species. As we currently know them, coral reefs have evolved on Earth during the past 200 million to 300 million years.

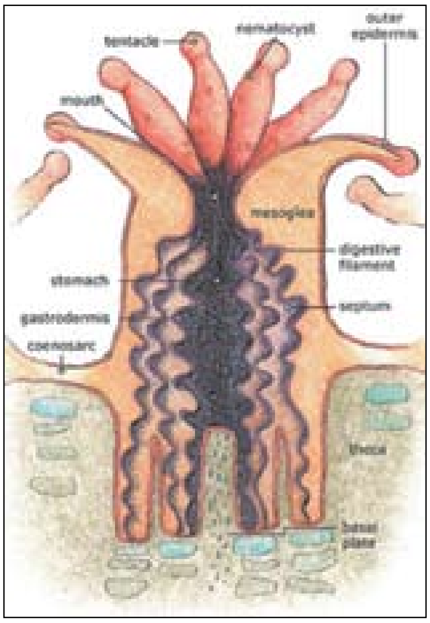

Figure 2.2. The anatomy of a coral polyp
Source: *NOAA Education Division.*

Where are coral reefs found?

Different types of coral reefs are found throughout the oceans, from deep, cold waters to shallow, tropical waters (figure 2.3). The tropical reefs found in South Asia and Indonesia are formed in a zone extending at most from 30°N to 30°S of the equator. Reef-building corals generally grow at depths shallower than 30 m (100 ft), or where the temperature range is 16-32 °C and light levels are high. Areas where coral reefs occur represent less than 0.015 per cent of the oceans, but harbour more than 25 per cent of the oceans' biodiversity. This is an amazing fact when you think about it – no other ecosystem occupies such a limited area with as many life forms.

There are three main types of reefs – fringing reefs, barrier reefs and atolls (figure 2.3) – as well as patch reefs that are common along many Indian Ocean coastlines. Fringing and patch reefs usually lie near emergent land. They border the coastline closely or are separated from it by a narrow and relatively shallow stretch of water. The reefs round Sri Lanka, continental India and the Andaman coast of Thailand are fringing and patch reefs. Barrier reefs grow parallel to the coast, but are separated from land by deep lagoons that are tens of, or even 100, kilometres wide. The largest and most famous barrier reef in the world is the Great Barrier Reef in Australia. Other notable large barrier reefs include those found in New Caledonia and Belize. Barrier reefs are not a common feature of South Asia. Atolls are large, ring-shaped reefs found far off the coast. They are formed when islands slowly sink under the sea (this may happen over many thousands of years because, for example, the volcanic activity that formed the island stops) while the coral reefs around the islands keep growing in order to stay close to the sea surface. This creates a ring of coral reef that surrounds a lagoon. The emergent part of an atoll reef is often covered with accumulated sediments, which creates islands. The most characteristic vegetation growing on these reefs tends to be coconut trees. Maldives and the Union Territory of Lakshadweep, India are built up of coral atolls.

Figure 2.4 shows the distribution of tropical coral reefs around the world. In Asia, extensive reefs are found in India (e.g., the Union Territory of Lakshadweep, Andaman and Nicobar Islands, Gulf of Mannar and Gulf of Kachchh), Indonesia, Maldives, Sri Lanka and Thailand. Smaller coral communities are also found in Bangladesh (e.g., St Martin's Island), Pakistan, and many other countries.

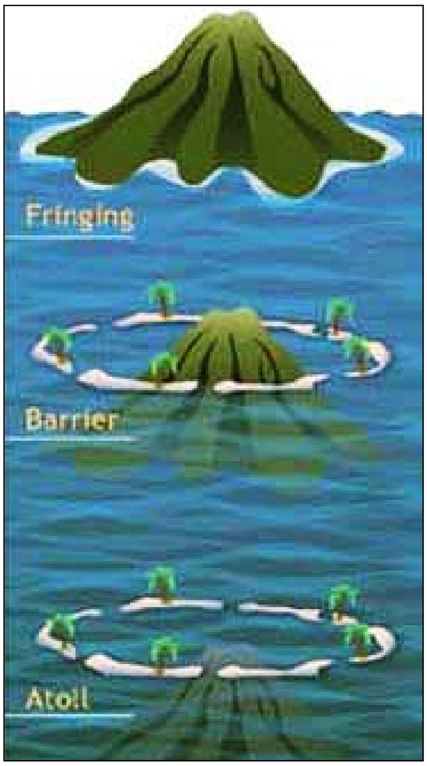

Figure 2.3. Three of the main types of reef (note: patch reefs are not featured)
Source: *NOAA Education Division.*

Figure 2.5. Animals found on reefs include fish and turtles
© J. Tamelander

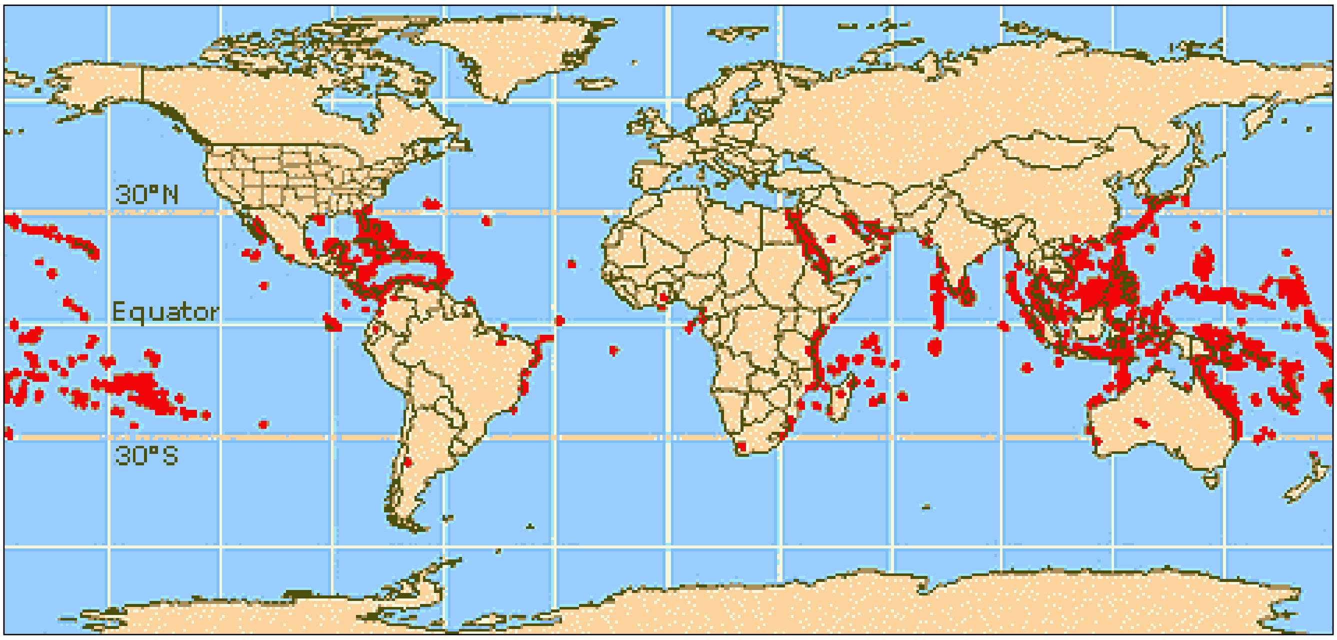

Figure 2.4. The global distribution of coral reefs
Source: *NOAA Education Division.*

Animal and plant life on coral reefs

The coral reef is like a city under the sea, teaming with life comprising thousands of species of colourful fish, sea plants and other creatures such as turtles (figure 2.5). The plants and algae that live there convert light energy into chemical energy through photosynthesis. As fish and other creatures eat the algae, this energy is passed on through the food chain. In the coral reef, as in all ecosystems, energy flows from the Sun to the plants, from herbivores to carnivores, to scavengers and decomposers, after which the energy cycle allows it to return to other parts of the food chain (e.g., decomposed matter forms nutrients for plants).

Figure 2.6. A coral reef food web
Source: *NOAA Education Division.*

Coral

The most unique feature of corals is the highly evolved form of "symbiosis" or mutual, positive relationship between the coral polyp and zooxanthellae – single-celled algae – that live inside the coral tissue. The algal cells utilise energy from the Sun through photosynthesis. This provides oxygen and food for the coral organisms to feed on. In return, the algae find a safe haven inside the coral. This kind of association is called a mutualistic association since both organisms benefit from each other. This symbiosis between algae and animals also contributes to the brilliant colours of coral.

While much of a coral's diet is obtained from zooxanthellae, they can also "fish" for food. Each polyp has a mouth surrounded by stinging tentacles. During feeding – usually at night when the algae inside the coral tissue cannot photosynthesise – a coral polyp will extend its tentacles out of its body and wave them in the water. When the tentacles come in contact with small organisms, plankton or other food particles, the stinging cells on their surface (called cnidoblasts or cnidocytes) stun or kill the prey, which is then passed to the mouth of the coral.

Fish

Some of the best-known fish inhabitants of reefs are butterfly fish, angelfish and damselfish, but in total almost 100 fish families can be found on a reef. These can be divided into functional groups based on what they eat, including carnivores (fish that eat other fish or animals), herbivores (fish that eat algae and other plants), planktivores (fish that eat plankton), and detritivores (fish that eat organic material such as the remains of other organisms). Different species and groups therefore have their place in different parts of the food web.

There are many different types of carnivores. Most sharks as well as certain groupers and snappers eat other fish, while others may eat small shrimp or shellfish. Many of these are popular food fishes and, as a result, are often over-fished in areas close to cities. Some triggerfish even eat sea urchins. The moray eel is generally nocturnal and spends its days lurking in caves, only coming out at night to feed on small fish.

Among the largest groups of herbivores are the parrotfish. Parrotfish have powerful teeth that have fused together to form a beak-like mouth, which is used to scrape algae off coral rock (although sometimes coral polyps may be eaten). The fish is able extract the food by chewing it up with its extra set of internal jaws. As a result, parrotfish contribute to creating the sand at the bottom of the reef. Surgeonfish are another group that grazes on algae, often travelling in large schools. While these herbivores are important as a source of food for carnivorous fish, they also serve a very important function in maintaining the reef ecosystem. By eating algae they actually help coral grow. Were it not for these plant eaters, many reefs might be overgrown with algae.

Some fish have evolved a very special role on the reefs, such as the cleaner wrasse, a small fish that helps other fish with their personal hygiene by eating parasites and dirt from their bodies and even from inside the mouths of carnivores. Because a fish being cleaned benefits from this, e.g., by reducing disease, it will not eat the cleaner wrasse, which in turn benefits by getting a good meal! Some animals "mimic" the appearance of other species for their own advantage. The sabre-toothed blenny, for example, mimics the appearance of the bluestreak cleaner wrasse. Unsuspecting fish are fooled into allowing the blenny to come close to them in order to clean them, but the cunning blenny bites the larger fish, getting a piece of fin or flesh as a meal.

There are also some fish that have evolved very special forms of self-defence. This includes the stonefish, so named because it is virtually indistinguishable from a stone. Because it is so difficult to see, it is easily stepped on. The stonefish is very dangerous as it has poisonous spines down its back that release a venom that can kill people. Another poisonous fish is the beautiful lionfish. Because of the poisonous spines on its fins it can hunt for prey – mostly small shrimps – without fear of predators.

Sea cucumbers, sea stars and sea urchins

Sea cucumbers, sea stars and sea urchins, together called *Echinoderms* (meaning "spiny skin") are easily recognisable and are important parts of the reef community. Sea cucumbers are sausage-shaped invertebrates that eat the sand to collect algae and organic debris from it. Creatures like the sea cucumber make sure that the reef floor stays clean, and help re-circulate food and energy in the system. The long spiny sea urchin also helps keep the algae in check. Its mouth is conveniently located on its underside for easy grazing. The urchin is well protected by its spiky exterior, and is likely to cause painful wounds if stepped on.

While most sea stars are in harmony with the reef ecosystem, there is one that can sometimes cause great damage. The Crown of Thorns starfish feeds on corals and occurs on many reefs naturally. However, sometimes, in part because of stress on the reef (e.g., due to pollution from human activities), the Crown of Thorns starfish become extremely abundant, and may eat large areas of coral reefs. Outbreaks of this animal have been observed in Asian countries such as Indonesia, Japan and Sri Lanka. The only way to deal with an outbreak is to physically remove individuals or kill each one with an injection of poison.

Other reef animals

There are many other interesting animals that depend on coral reefs. Reptiles, such as marine turtles, are common visitors to reefs. There are five species of marine turtle in Asia. The most common ones seen on coral reefs are the hawksbills, although green, loggerhead and olive ridley turtles may also be found. There are also several species of sea snakes that can be found in parts of the Indian and Pacific oceans. Marine mammals, such as dolphins, occasionally come in to feed in coral reef areas.

2.3. Mangroves

Mangroves are tropical trees and shrubs that are able to survive in saline and brackish water (the word "mangrove" can refer to an individual species as well as an entire swamp forest). They occur naturally in sheltered coastal areas, such as river mouths and estuaries where freshwater and seawater mixes, tidal creeks, backwaters, lagoons and bays. The character that all mangroves have in common is that they can develop more successfully where there are tidal fluctuations. This is a major factor that determines their distribution.

Mangroves have many special characteristics that distinguish them from other plants. All these characteristics are adaptations to saline and flooded conditions. One of their most visible adaptations is the production of long "prop roots" (figure 2.7) from the trunk and branches, which help the trees to become very stable by anchoring them in the soil and enabling them to withstand tidal forces as well as storms. They also help trap sediment around the tree, and in this way mangroves help to create their own living environment. The roots also have pores on them called "lenticels", which help the tree to breathe.

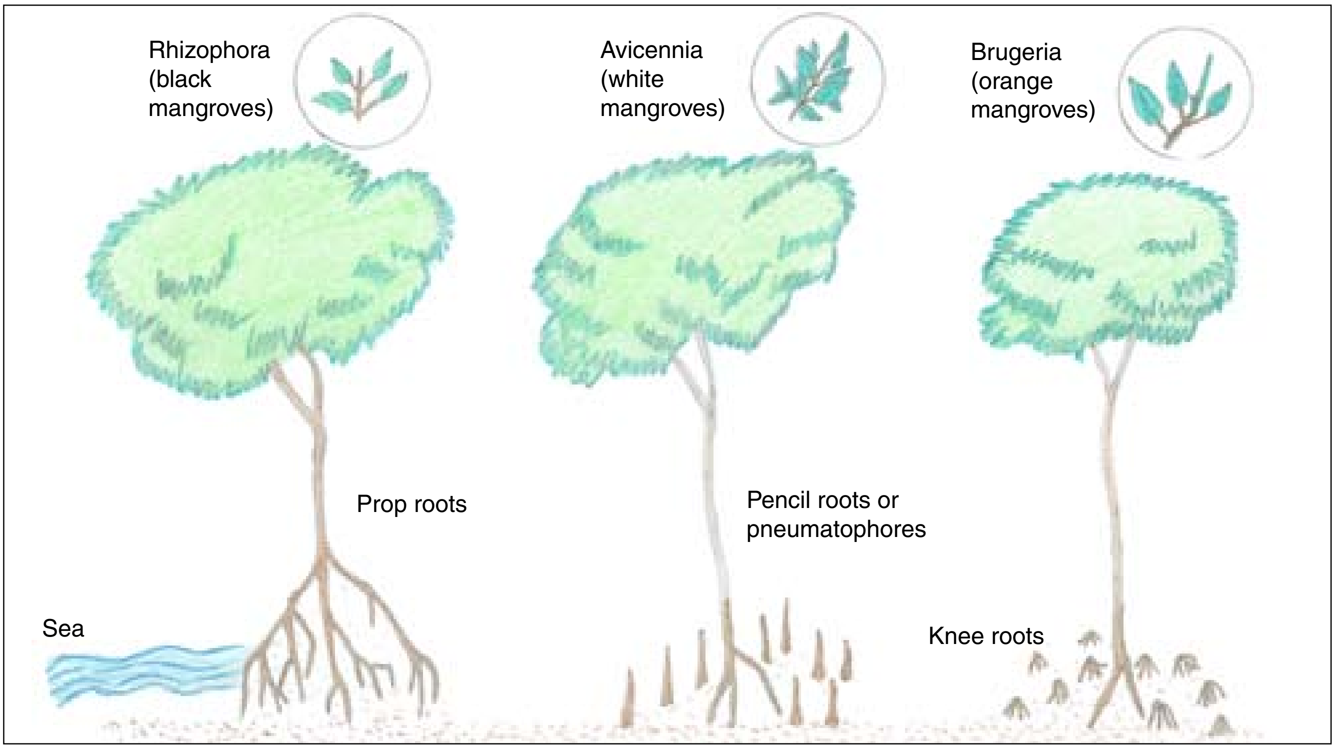

Figure 2.7. Different types of mangrove trees and their adaptations
Source: *S. Rao, 1996; redrawn by B. Begum.*

Another adaptation is the growth of "pencil roots" or pneumatophores. These are specialised roots that grow upwards in the air like sticks growing up from the ground, and help the trees to access oxygen. This is important because the sediments in mangrove forests often lack oxygen. "Knee roots" serve a similar function.

To manage the high salt content in their environment, mangrove leaves have special adaptations that include salt glands on the leaves, which can secrete excess salt from inside the leaves. Also, mangroves have filters on their roots to keep salt out, while in some trees the leaves store extra water to balance the salt content. Figure 2.7 shows some of the unique adaptations of mangrove plants.

To ensure good conditions for the growth of seeds, mangroves have a special adaptation called vivipary. The seed germinates while still attached to the mother plant, and the seedling grows and becomes bigger and stronger until it is released. This is called a propagule. The propagule falls down and becomes lodged in the soil or mud, or may be transported with the water somewhere else to anchor and grow. Because the propagule carries a developed small plant it can immediately start putting out leaves and roots if it finds a suitable environment.

Common mangroves found in Asia include *Rhizophora*, *Bruguiera* and *Ceriops* species. Patches of mangrove are widely distributed in tropical coastal areas across Asia and the greatest mangrove species diversity is found in South-East Asia. The largest area of mangrove forest in the world is between Bangladesh and India in the Sundarbans. Indonesia also has substantial mangrove areas.

Animal and plant life in mangroves

Mangroves provide an important habitat for a special group of organisms that form the detritus food chain. When mangrove leaves decay on the muddy forest floor, many species of bacteria and fungi help in decomposition. This is the food for many species of molluscs, crabs and insects. The wastes of these animals provide food for juveniles of fish who are, in turn, eaten by eels and other carnivores. Mangroves are also called the nurseries of the ocean as many fish spend their early years feeding in the safety of mangrove ecosystems before starting their lives in the sea.

Some common animals found in mangrove ecosystems are:

- Upper roots – periwinkles and barnacles;
- Lower roots – oysters;
- Muddy forest floor – prawns, mud crabs, fiddler crabs, eels, mudskippers and frogs.

Other life animals found in mangroves include:

- Insects – mosquitoes, ants, bees and beetles;
- Reptiles – snakes, monitor lizards and saltwater crocodiles;
- Birds – egrets, herons, sandpipers and kingfishers;
- Mammals – monkeys, bats, deer, buffaloes and tigers.

2.4. Salt marshes

Salt marshes usually form in areas that are well sheltered with tidal currents that are gentle enough to allow vegetation to grow, and where fine sediments can be deposited, such as creeks, bays and estuaries. Salt marshes are exposed at low tide and at least partially flooded at high tide, so only salt-resistant forms of vegetation can grow there. They are typically very flat, with numerous muddy channels and creeks cutting through them. The plants found in salt marshes have extensive root systems that enable them to withstand brief storm surges, thus buffering the impact on upland areas. A distinctive feature of salt marshes is their colour, as the plants found in those habitats tend to be different shades of grey, brown and green.

Despite their value, salt marshes are too often considered to be worthless. However, salt marshes are important for many reasons. They provide a habitat for animals in various stages of their life cycle. Smaller animals can hide in marsh vegetation, because the shallow areas physically exclude larger predator fish. As salt marsh plants die and decompose, they form organic matter, which provides a food source for other organisms in the salt marsh. Tidal waters move up into the marsh and then flow back into the sea, distributing this organic matter throughout the estuary.

Salt marshes also act as filters. Tidal creeks meander through the marshes, depositing valuable nutrients as well as pollutants from upland development. Salt marshes can absorb or trap some of these nutrients and pollutants, reducing the load entering estuaries and the sea. In this way, salt marshes prevent sediments from washing offshore where they can smother other ecosystems. This also often creates more land on which salt marshes can grow.

Animal and plant life in salt marshes

Salt marshes are composed of a variety of plants, such as rushes, sedges and grasses. Salt marshes provide nursery areas for fish, shellfish and crustaceans. Young fish often have a varied diet and forage for food in the mud of the marsh bottom as well as eating the plants and smaller organisms that live in the salt marsh ecosystem.

Some salt marsh habitats are very important for conservation. The seasonal salt marsh in the Rann of Kachch, which covers a large area including the north-west of India (Gujarat) and south-east Pakistan (Sindh), provides a critical habitat for the last population of the endangered Asiatic wild ass. It also supports one of the world's largest breeding colonies of greater and lesser flamingos.

Figure 2.8. A salt marsh in Puttalam, Sri Lanka

© G. Sriskanthan

2.5. Seashores

The area where land meets the sea – called seashore, shoreline or coast – can be classified according to what it is made up of, and shorelines are typically rocky (hard), sandy or muddy (soft). Seashores are rich in flora and fauna, and the material that makes up a shoreline also greatly influences what species it is host to. Seashores are dynamic environments, with many physical processes that change daily, as well as seasonally, affecting how coastlines form. Waves, tides and currents all result in the "deposition" or putting down of particles that make up the shore, as well as "eroding" or breaking down the shoreline that is already there. These may change with different seasons. Given the tidal changes daily, as well as seasonally, the shoreline will be subjected to many different conditions throughout the year. Most of the organisms that live on the seashore are specially adapted to survive well in such a dynamic environment. The picture in figure 2.9 shows some of the organisms that one might encounter on a seashore.

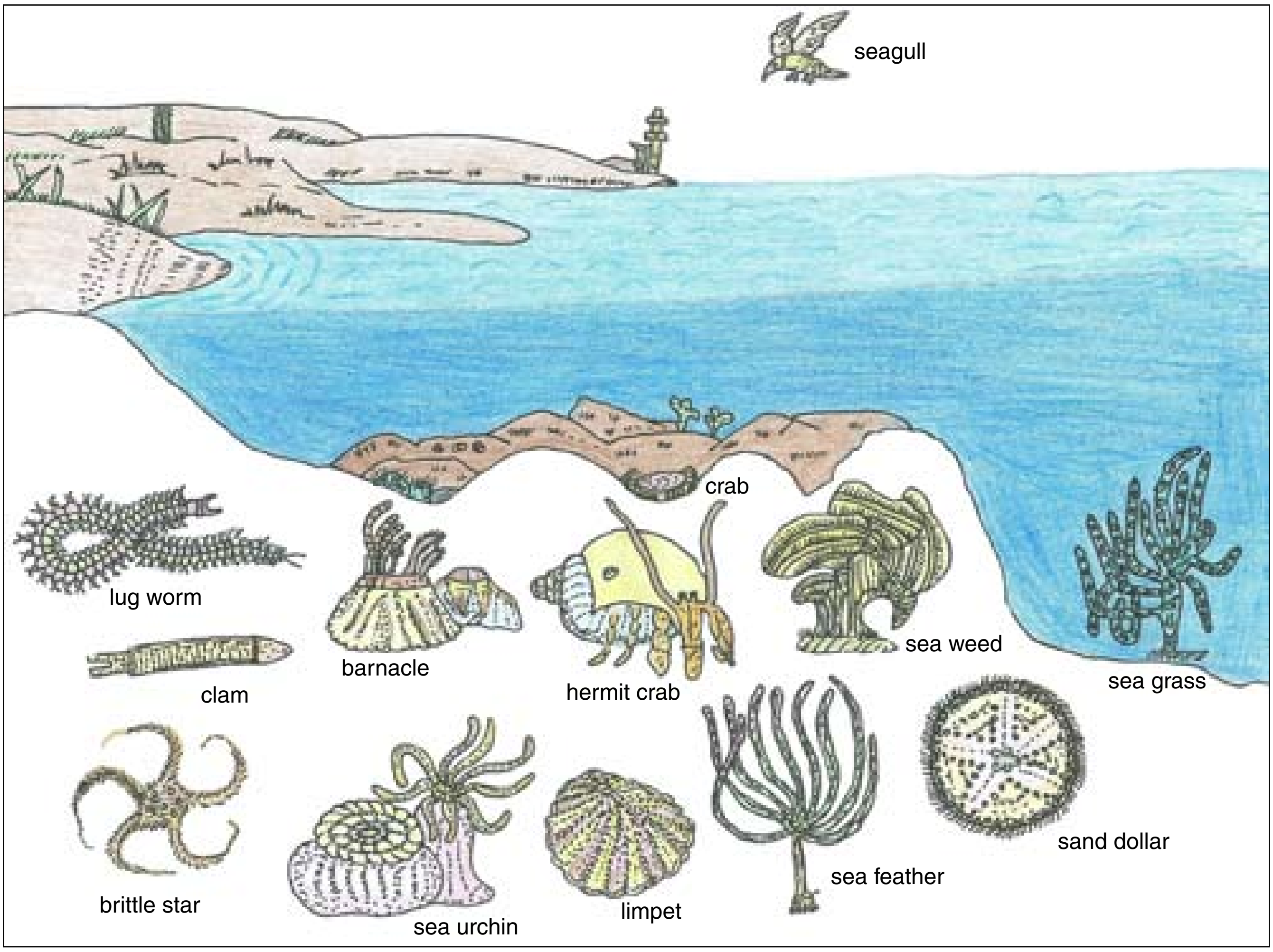

Figure 2.9. Animals and plants often encountered on the seashore
Source: *Adapted from S. Rao, 1996; redrawn by B. Begum*

Rocky shores

Rocky shores are sections of the coasts where rock outcrops and the sea meet, and are often found where mountain ranges are near the coast (e.g., some areas of the western coast of India). Characteristic animals of the upper rocky shore include barnacles, limpets, chitons and winkles as well as crabs. As wave energy is often high, many plants and animals need to be firmly anchored to the rocks in order not to be swept away. They have solved this problem in different ways. Kelp is attached by growing into crevices and around edges of rocks, and the leaves and stems are often short and tough. Oysters firmly cement their shells to the rocks and can close completely if exposed to air at low tide, while gastropods can attach themselves by making a tight seal between their shells and the rocks, creating a vacuum.

Seaweed is actually multi-cellular algae and is often found on and around rocky intertidal coasts. Seaweed does not have different specialised parts such as leaves, roots and a stem unlike plants, although most do have root-like structures (holdfasts) for attaching to the rock. Because they live in water, all parts are used to absorb water and nutrients – so their leaves are at the same time their roots. While algae are a natural part of the ecosystem they may become very abundant as a result of nutrient pollution. This can negatively affect other organisms, including coral.

There are three main types of seaweed – green, brown and red. The different colours are due to different pigments used by seaweed for trapping solar energy during photosynthesis. Green seaweed is usually in the form of lush, leafy or thin filaments, and some types are edible. Green seaweed prefers shallow water, but some types manage to live at considerable depths, down to 30 m.

The brown seaweed, or kelp, is mostly thick and fleshy, and can form dense forests. It may also get torn off by waves and storms and is often seen on the sea surface, as many forms have small vesicles that make them float.

Coralline algae are a form of red seaweed. They could well be the most amazing plants in the sea, as they are found from the shallowest rock pools to greater depths than any plant can grow; and from the cold temperate seas to the warm tropical coral reefs where they serve an important function in cementing together rubble. This places them among the most important reef builders.

Sandy and muddy beaches

Sandy beaches are formed in part through the erosion of coastal rocky shores, which produces sand, and from sand being carried from inland by rivers. Many beaches in Asia are also made up of large amounts of materials such as shells, bits of coral and mineral materials from some algae that are washed ashore by waves and currents.

Muddy shores are found along coasts that are close to a river mouth, where rivers bring silt from inland and deposit it on the shore. This includes, for example, some areas on the coast of Bangladesh. Plants found on sandy shorelines include coconut palms, sand binders such as ipomoea (a sand dune-binding plant). Sandy shorelines are also home to animals such as ghost crabs and sand-hoppers, for example. In shallow sandy areas, there are many burrowing bivalves (mussels) as well as different types of worms that mostly feed on tiny algae that live on and between the grains of sand as well as on detritus.

Muddy shores are made of up very fine silt or mud, and have different characteristics to those of sandy shores. These types of shores provide a good habitat for many different species, and distinct ecosystems can be found in muddy areas. Mangroves and marshes (see sections 2.3 and 2.4) are both examples of ecosystems that have developed on muddy shores.

Seagrass meadows

Seagrasses are the only flowering plants (angiosperms) that can live submerged in shallow marine waters. As seagrass plants depend on sunlight for photosynthesis, they only occur in relatively shallow water. They are generally found in sheltered, soft-bottomed marine coastlines and estuaries of the world (figure 2.10). Seagrasses are important because they provide nurseries and foraging habitats for fish and shrimps, and a food source for larger animals including the dugong, a marine mammal that is now absent from many areas due to hunting. They also help to stabilise sediments by reducing sediment re-suspension and by dissipating the effects of wave action during high tide, thus assisting in reducing beach erosion. Seagrasses often occur in association with coral reefs and mangroves, and torn-off leaves – mostly brown as opposed to the green colour of live seagrass – are a common sight where they accumulate along many beaches.

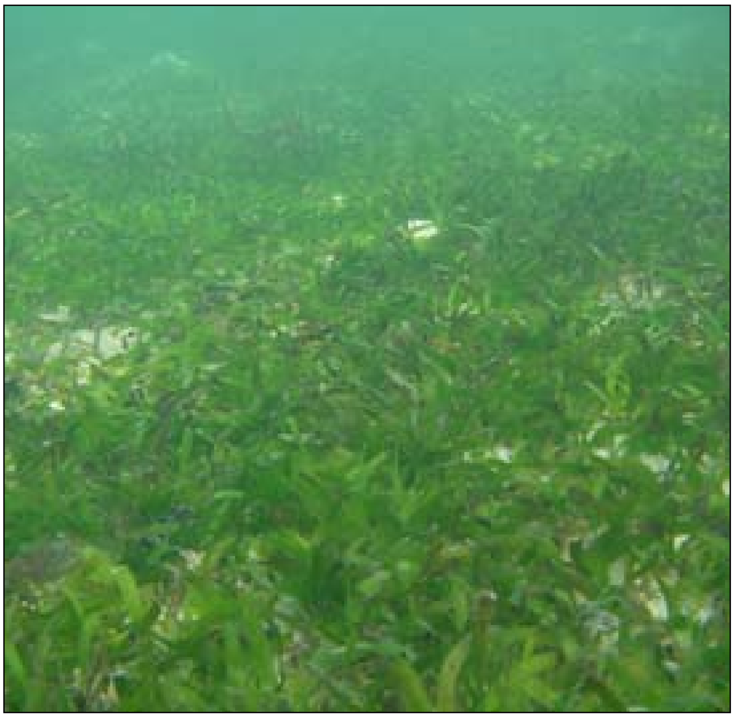

Figure 2.10. A seagrass bed

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2.6. Estuaries

An estuary is a partially enclosed area of coast where freshwater joins and mixes with seawater. Estuaries are often found in low-lying coastal areas, and are generally associated with the mouths of rivers. Sedimentation or silt carried by rivers and streams from inland areas is deposited in estuaries. This creates a shallow area of mixed salt and freshwater, which provides a unique, nutrient-rich environment with high biological productivity. Estuaries are some of the most important areas of the oceans, and many different ecosystems, such as mangroves, are actually found within estuarine areas. Like salt marshes and mangroves, they act as safe feeding grounds for different organisms, providing shelter from the open ocean and predators. They act as nurseries for the young of different coastal and marine species, and are the place where millions of ocean creatures such as prawns and certain fish species begin their lives.

Animal and plant life in estuaries

Estuaries provide habitats for shellfish such as clams, mussels and oysters as well as for many fish species. Because estuaries are so nutrient rich, they provide plentiful food for the different organisms living in them. Larger animals, such as wading birds and sea birds, visit estuaries and depend on them as a rich food source of fish, crustaceans and shellfish. The largest estuarine delta in the world – and also the largest mangrove area in the world – is the Sundarbans, straddling the east coast of India and Bangladesh. The area is of great conservation value for many reasons and is home to the biggest group of the highly endangered Royal Bengal Tigers.

2.7. Urban coastal ecosystems

Some of the largest cities in Asia are found in coastal areas. Although we do not think of urban areas as being part of nature, these environments also have their own characteristics and support different species that are a part of urban ecosystems. Urban coastlines are generally built up and are affected by a great deal of pressure from human development. Natural ecosystems that may have once existed in urban areas tend to be broken up into smaller fragments, altered completely or, in some cases, destroyed by development such as the construction of ports, jetties, breakwaters and seawalls.

Many coastal cities still have remnant mangroves, especially along creeks and rivers as well as beaches and estuarine ecosystems, and these can still play a role in regulating urban ecosystems. For example, small areas of wetlands can have an ecological function in processing organic pollution from cities; sandy beaches provide a recreational value for city dwellers; and in some cases, small areas of mangroves can act as a buffer against storms and extreme weather events. Trees in cities, including mangroves in coastal areas, help to reduce air pollution, act as carbon sinks, and affect the microclimate of urban areas, which can be felt in the ambient temperature and air quality. Since so many people live in urban areas, it is important for them to recognise the fact that even in a city they share their space with, and indeed depend on, other organisms that play a vital role in maintaining the health of urban areas.

Animal and plant life in urban coastal ecosystems

Built-up, urban coastal areas can harbour a wide range of plant and animal life, usually species that are found elsewhere along rocky, sandy and muddy shores. However, the composition of these species often differs from natural areas, and tends overall to be less diverse.

Sea birds near urban areas are attracted by readily available food sources, including waste, and can often be seen foraging for food in urban garbage. Monitor lizards are hardy generalists who survive well in built-up coastal areas, and thrive in remnant patches of mangrove and estuarine environments. Marine turtles continue to nest in heavily populated and highly-altered beach ecosystems in or near urban coastal areas; even though their nesting activities may be negatively affected by urban development (especially by lighting and construction too close to the beach), the possibility for them to co-exist and survive in urban ecosystems can be supported. However, many organisms are very negatively affected by heavy urban development. For example, while many urban areas in Asia share their coastlines with coral reefs, the animals and plants associated with reef ecosystems, especially corals, are sensitive to water quality and usually disappear near cities as a result of sedimentation and nutrient pollution.

Figure 2.11. The urban coastline of Colombo, Sri Lanka

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2.8. Suggested activities

OUTDOOR ACTIVITIES AND GAMES

(a) Recipe for an ecosystem

Purpose: It is recommended that this activity be carried out before any other activities as it will serve as an introduction to the concept of ecosystems. The aim of the activity is to make children aware of the components of an ecosystem.

Equipment: Each group should be given drawing paper and coloured pens/colouring pencils for listing the components of their ecosystem.

Activity: Create groups of 4-5 students and ask them to create a new ecosystem (preferably local) by giving them an imaginary piece of land or water body. Ask them to put in as many animals or plants as they like, but note that their ecosystem should have all the correct ingredients including both biotic and abiotic components, producers, consumers and decomposers. This will give them the context with which to understand and explore ecosystems using the activities suggested in this toolkit. Get them to list all the different components of the ecosystem. They can use different colours for different groups (e.g., one colour for consumers, another for decomposers etc.).

When their ecosystem is ready, discuss their ideas and find out which local plants and animals have been listed, and brainstorm how they can make their ecosystem functional and as close to nature as possible. Check whether the energy source (the Sun) has been included in their ecosystem.

(b) Group excursions

(i) Basic rules during all field excursions:

- Teachers must accompany students on excursions;
- Teachers should visit the site before the student activity or be very familiar with it;

- Many areas are best visited at low tide – check the time of low and high tide (tide tables are usually available e.g., from the ports authority), and keep track of time and tides;
- Everyone must be on time, and be prepared to get wet and dirty;
- Wear waterproof shoes and cotton clothes;
- Use insect repellent and sun screen;
- Always go in pairs, whether walking in mangroves, along a shore or snorkelling in seagrass beds and coral reefs;
- Observe the animals and plants, but do not touch or collect;
- Do not lift old logs, corals or rocks to see what's underneath – some animals may bite if they are disturbed;
- Take your litter back with you.

Students should be encouraged to take notes, maintain a diary of trips, take photographs, or draw pictures during or after each excursion if they want to.

(ii) *Mangroves*

Take a group of students to a mangrove site. Split them up into smaller groups and give them some of the following tasks:

- Identify the mangrove species and their adaptations;
- List the different species of animals (e.g., molluscs, crabs, reptiles and birds) that they observe once the tide has gone out;
- List the different types of adaptations observed (e.g., use of mud, prop roots, pneumatophores, tree branches);
- List the ways humans have used the mangroves from that particular site (e.g., wood cutting, to make way for a garbage dump etc);
- Observe if the area is being degraded or is well conserved.

(iii) *Shores*

Organise a visit to a nearby seashore with students to observe the different aspects of the shore, such as: shore type, quality and morphology. Include a walk along the seashore with the students. Provide them with suggested observations that they should record, such as:

- Type of shoreline;
- Shape of the shoreline;
- Types of animals and plants observed (alive or dead). Discuss why they are dead and what this may reveal about the ecosystem;
- A list of observed human activities, including any harmful activities.

(iv) *Coral reefs*

Take a group of students to a coral reef site. If facilities exist and students are able to swim, use snorkels or glass-bottomed boats to take the students closer to the reef ecosystems. Ensure that the students are able to snorkel without causing damage to the coral. Students should not touch or stand on the coral. Divide the students into small groups and ask them to:

- Observe the shapes, sizes and colours of coral, fish and other animals or plants;
- Observe and describe an animal's activity on the reef;
- Observe and describe the condition of the water (e.g., visibility, waves);
- List observed human activities, including any harmful activities, record the amount of litter and identify possible signs of other pollution.

(c) Transect walk/transect snorkel/glass-bottomed boat transect

Purpose: A transect study basically consists of observing and recording the species and characteristics along a straight line of a given length of a coastal ecosystem. It can be used to describe an area, its species and health status.

Equipment: Between 10 m and 20 m of rope for marking out the terrestrial transects. Each student should carry a notebook and pen to make notes.

Activity: In the case of land-based ecosystems (e.g., mangroves, salt marshes) the area to be studied should be marked in a straight line with the help of the rope. The length of the rope depends on the area under study and the numbers of investigators, but should be at least 10 m. The plants and animals that are touched by, or are directly under the rope should be listed in a notebook.

If transects are being carried out in the water over coral reef ecosystems, students should be asked to snorkel or take a glass-bottomed boat in a straight line for approximately 10 m (land marks can be used to assist with measuring distances) and observe all the underwater animals, plants and coral structures that they see. Many transects can be studied in a single field excursion. What the students see along their transects and the differences between observations by different groups or sites can be discussed.

(d) Quadrat sampling

Purpose: Quadrat sampling can be used to understand the biodiversity of an area as well as for finding out the relative abundance of different species. This activity can be carried out on marine ecosystems by much practiced individuals; however, for inexperienced students it is better to carry out to do it on terrestrial ecosystems, such as mangroves or salt marshes.

Equipment: To make a quadrat, create a wooden frame or PVC pipes in the shape of one square metre, or place pegs in the ground to mark out one square metre in string. Each student should carry a notebook and pen.

Activity: Place a quadrat in the ecosystem that is being studied. All animals and plants that occur in the quadrat should be listed and the numbers of each species should be estimated. If animals are easy to count (e.g., snails on a rocky shore), the total number of animals can be recorded. On soft substrates it is important to also look for organisms inside the sediment.

For plants, the students can estimate the area of the quadrat covered by a certain plant (e.g., 20 per cent cover). Many quadrats can be placed in different areas of the ecosystem. Students can discuss what was found in their quadrats as well as the differences between observations by different groups or at different sites.

Figure 2.12. Students using quadrats to study a rocky shore

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(e) Coral feeding game

Purpose: This game will help the students understand how corals feed and will provide them with an introduction to concepts of mutualism, water currents, and how plants and animals in the ocean are connected to each other.

Equipment: You will need items such as popcorn, small biscuits or an equivalent food, and a spoon.

Activity: Start by asking children what is a coral? Is it a plant, an animal or a mineral? Explain that a coral is an animal. Discuss the structure of coral polyps and explain the role of the symbiotic algae zooxanthellae (see section 2.2).

Ask the children what they think corals eat. Explain that coral polyps eat small organic matter such as algae and plankton. Also explain how, during the day, it is easy because the algae residing in the polyp's body create food from sunlight through photosynthesis. Zooxanthellae produce 60-90 per cent of nutrition for the coral; therefore, to a great extent, they determine the coral's lifestyle. Most corals cannot live without them. Because of this, the coral does not need to struggle to find food and provides a home for the zooxanthellae in return for the provision of energy through photosynthesis.

Figure 2.13. Students playing the feeding game

© V. Hoon

- *Game for explaining mutualism*

Have the children stand together with their hands crossed. Give them a spoon each, with one small piece of food (e.g., popcorn or a small biscuit) and ask them to toss the food into their own mouths. Afterwards, ask the children to feed each other instead with the food and then get them to discuss which was easier. Ask them what the term is for describing two living organisms that help each other to meet their needs. Explain that this is referred to as a symbiotic relationship, or mutualism, and tell the children how coral has a symbiotic relationship with the zooxanthellae living inside the coral.

Ask the children what they think corals do at night when the algae cannot produce food. How does it eat at night? Explain that it uses its tentacles to catch plankton. Also discuss similarities and differences between the coral-zooxanthellae symbiosis and other mutualistic relationships that occur in nature, e.g., sea anemones and anemone fish. The anemones' stinging tentacles provide the little anemone fish (also known as clownfish) with protection from predators while the anemone fish defend the anemone, chasing away butterfly fish which like to eat anemones.

- *Game for showing how coral feed*

Group the children close together like a coral colony, and tell them to pretend that they are attached to each other. Tell them to extend their arms above their heads and wave them like tentacles searching for plankton. The game facilitator should stand away from the group holding a bag of food, throwing pieces of food towards the "coral colony". The facilitator is the source of plankton, and the force with which he/she can throw the food is the current that is bringing the food toward the coral colony. After the game, discuss with the children whether it was easy or hard to catch the popcorn, and what would happen when the "current" becomes weak and the food cannot reach them. End the lesson by discussing why we need to care about corals, explaining how corals also provide important habitats for other organisms.

(f) Food web game

Purpose: The transect and quadrat exercises give students an understanding of the species composition and biodiversity of different ecosystems. The food web game will make them aware of the associations between these different species. This game explains to the students how each organism is dependent on others for survival, and that a break in the food chain can have disastrous consequences for particular species.

Equipment: Paper and pen for students to list ecosystem components. Small-sized drawing paper and coloured pens/paints/colouring pencils for each student to draw the ecosystems components.

Activity: Make a list of animals and plants as well as abiotic factors found in the ecosystem. Make sure that there are various types of herbivores and carnivores, plants, and things such as freshwater, seawater and sunlight. There should be at least as many items on the list as there are students in the class. Assign each student one item from the list. Students will have a few minutes to write or draw their assigned item on a piece of blank paper.

Next, have the students stand in a circle in the middle of an open area in a field, classroom or playground. Give the student identified as the Sun the ball of rope and get that student to name the organism he or she is, and the name of an organism he or she associated with for survival. For example, the Sun produces light that the mangrove depends on for photosynthesis. The Sun will throw the ball of rope to the mangrove, holding on to the end of the string. Repeat the process – a mangrove tree might depend on the muddy soil, so it throws the rope to the person identified as muddy soil, while holding on to the rope. The muddy soil in turn may depend on regular tidal inundation and so on. If the rope comes to either water or the Sun, the student playing that part should then toss the rope to an organism he or she supports. It is acceptable if a student gets the ball of rope more than once. Repeat the process until each student is holding a piece of the rope. By this time, there should be a rope web connecting everyone in the ecosystem together.

Once each student has a piece of rope, the teacher then states a man-made chance (such as sea-level rise, global warming, deforestation or fishing), or a natural event (such as a hurricane or tsunami) in the environment. Any student (playing the role of their assigned organism) potentially overcome by that change drops the piece of rope and exits the circle or sits down. Any organism relying on the affected organism will also be influenced and should drop the string. Eventually, nearly all organisms are affected. The students will see the results of a small change in the food chain. Will this scenario also affect the Sun and/or water?

This process is repeated as many times as necessary, using different scenarios so that only the Sun is still holding the rope (water may also still be holding the rope, depending on how severe you decide to make the climate change process). How are humans and, more specifically, individuals affected?

(g) On the spot sketch of the ecosystem

Purpose: To allow students to explore ecosystems using drawing as a medium.

Equipment: Drawing paper/chart paper and paints/coloured pens/colouring pencils.

Activity: Students who are artistically inclined can be asked to draw a sketch of the ecosystem showing the plants, animals and human activities at the site. If the student lives close to the ecosystem under study, he/she can be asked to draw the site at different times during the day. This will make them understand the daily cycle of natural processes (such as the daily changing tide and light) and human activities that occur at the site, and discover that this may affect the animals that inhabit the ecosystem or visit the site.

CLASSROOM ACTIVITIES AFTER THE FIELD TRIP

(a) Excursion feedback, talk, essay

During the excursion the children will have made many observations, as students may have been asked to take notes, maintain a diary, or take photographs during the excursion. On the day after the excursion, in the classroom, the students can be asked to give a talk on what they learnt during the excursion and/or write an essay on the ecosystem that they visited.

For the essay, ask the students to either:

- Select any organism they identified and write a two-page essay describing the following: its form (e.g., shape, colour and size); its habits (e.g., its diet, protection, reproduction and movement); any interesting or unusual features; and ways in which it might be affected by human activities and how it might be protected; or
- Decide upon another one or two possible topics.

(b) Write a poem, using the cinquain method

Purpose: This activity improves the language skills of the students while getting them to think about coastal and marine ecosystems.

Activity: A cinquain is a poem of five lines. The first line should be composed of one noun; the second line should be composed of two adjectives; the third line should be composed of three or four verbs; the fourth line should be composed of one short sentence; and the fifth line should be a synonym of the noun on the first line. An example of a cinquain written by a student in India on the noun "dolphin" is given below.

Dolphin
Sleek, gray
Helping, pointing, directing
My friend in the sea
Cetacean

These short poems help the students to concentrate on a species or part of an ecosystem and find out more about it. These poems can be displayed in the class and published in the schoolbook.

(c) Drawing of specific animals

The children can be asked to recollect the animals and plants that they saw during the excursion and to draw one of them. Try to cover most of the animals and plants listed in the field notebook. The drawings can be put up on the class notice board or stuck on card sheets and used in games such as the food web game.

(d) Inventory of plants and animals observed

Purpose: This activity will help the students to think about the different kinds of species found in an ecosystem, with regard to their importance to humans, their conservation needs and their positive or negative role in the ecosystem.

Activity: All the animals and plants observed in the excursion should be listed and then categorised according to whether they are: commercially important (e.g., fish caught for food or mangrove products that are collected for use); endangered or threatened (e.g., rare species such as sea horses, tigers and sharks); or whether they are endemic, alien/introduced species (if known). The species list can also be organised according to different categories such as producers and consumers, or associations such as parasites, symbiotic etc. At this stage, the teacher can also assist the students in finding the role of the species and its adaptations in the ecosystem. This will allow the students to explore the types of relationships and connections between different species in an ecosystem.

(e) Draw a chart showing a food chain, food web and trophic diagram

Purpose: This activity will help the students to explore how different species within an ecosystem are inter-related.

Equipment: Drawing paper and coloured pens/paints/colouring pencils.

Activity: Again, using the species list the teacher can assist the students to draw a food chain and a food web as well as a trophic diagram.

- Food chain: This will be a diagram showing the linear link between specific species, with a primary producer at the bottom, followed by a herbivore and then a carnivore, and sometimes with a final carnivore that predates the previous carnivore.
- Food web: This will be an expanded version of the food chain, and will link many more species found in the ecosystem together in a similar manner to the food chain, but will include the cross links between different food chains. As not all the species will have linear relationships, this diagram will look like a web, with many inter-connections.
- Trophic diagram: This shows the biomass of each "trophic level", which is the position or level that an organism occupies in the food chain. An example of a student's representation of a trophic diagram is given is given in figure 2.14.

Figure 2.14. Trophic diagram drawn by a student

© T. Khan

The students can be asked to draw these on chart papers as a group activity. They can either draw the plants or animals, or collect pictures and stick them on the chart.

(f) Film shows/quiz/talk by experts

To maintain the interest of the students in coastal ecosystems, a few activities that involve film shows, talks, quizzes and performances by local drama groups can be organised at regular intervals throughout the school year.

Short films or slide shows of 15-20 minutes duration can be shown and followed by discussions about the subject matter in order to help the students to understand local ecological and environmental issues. For example, the web links below are to two short films that provide an introduction to food webs in a coral reef ecosystem.

www.teachersdomain.org/resources/hew06/sci/life/reg/foodweb/index.html
www.teachersdomain.org/resources/hew06/sci/life/reg/nightreef/index.html

Local leaders, knowledgeable persons, scientists or local administrators can be asked to address the students and tell them how and why they work, and how their work affects the ecosystem and what they have learnt from it. If there is a marine or coastal protected area in the vicinity, they can often be interesting areas to visit and may be able to provide materials, tours and lectures. This will help the students to understand and value the knowledge of the people of their village or island.

(g) Human activities and ecosystems

During the excursions the students can be asked to observe evidence of human activities and list them, and to estimate the number of people engaged in each activity. A visit to the seashore may show the following types of activities: the use of “tetrapods” or cement blocks to prevent sea erosion; fishing; swimming; boating; boat cleaning and repairing; garbage collection; people relaxing; children playing; and fish nets drying and net repair activities.

In case an excursion is not possible, the teacher can ask the children to list the activities people engage in within their community (these include activities such as fishing, gleaning or garbage dumping, planting trees, taking care of a garden, washing clothes etc). They should then list all the activities on the board and discuss the impact of each of these activities on the ecosystem. The teacher can then highlight how unsustainable use, such as over-felling of mangrove forests, over-fishing or over-harvesting of medicinal plants from the ecosystem weakens the web of life and the ability of the ecosystem to revive.

Wherever there are examples of restoration or protection, or selective extraction from ecosystems, the teacher can highlight why these processes are needed for the survival of the ecosystem as well as for the survival of the students. In the classroom, there can be a discussion on the negative and positive ways in which people can have an impact on an ecosystem.

(h) Ecosystem replica in classroom

Purpose: In order to keep the excursion alive in the minds of the students, teachers can help the children to make ecosystem or species replicas.

Equipment: Coloured paper, glue, newspapers, cardboard, cloth, paint – in fact, many different materials are potentially useful, including recycled rubbish or discarded household items.

Activity: Supervise the students in making colourful paper or cloth models of the plants and animals, and even a small replica of an ecosystem or even just a single species. This replica can be placed in a corner in the classroom and used as a teaching aid. An example can be seen in the photo taken of a “diorama” or turtle model developed by children in the Andaman Islands (see figure 2.15). A group of children can be asked to visit the ecosystem regularly and observe if any area is being destroyed or changed in any way, including, for example, littering. They can also look for new or young animals such as chicks or hatchlings.

After every visit the students can:

- Make the changes in the classroom’s ecosystem corner;
- Give a talk on their observations;
- Keep a record of the monitoring process.

Figure 2.15. A colourful paper model of a turtle made by students in the Andaman Islands

© V. Hoon

(i) Ecosystem news board

A group of students can be made responsible for gathering news articles about ecosystems or environmental issues that are reported in daily or weekly newspapers or other printed sources of information. The students should then place them on a noticeboard kept in a prominent place. Each month a different ecosystem can be highlighted.

3. Social and economic significance of coastal and marine ecosystems

This section explores the importance of coastal and marine ecosystems to society, local cultures and economies, and encourages students to understand local history and traditional knowledge connected with these ecosystems.

Specific objectives

After completing this section the students will be able to:

1. Understand the contribution of coastal and marine systems to their local environment, culture and economy;
2. Understand the economic value of ecosystems;
3. Value local history, geography and development;
4. Compare their own as well as the local community's relationship with nature.

3.1. Why are coastal and marine ecosystems important?

In coastal and island communities, coastal and marine ecosystems can be very important to the day-to-day life of people in a number of different ways. Many communities depend on natural resources for their livelihoods. Activities such as fishing, shellfish collection, seaweed farming, mangrove wood collection and coastal tourism depend on healthy coastal and marine ecosystems. These ecosystems can also play a vital role in protecting coastlines from extreme events (such as storms, cyclones and tidal waves) and erosion. Healthy mangrove forests and coral reefs can act as buffers against storms and waves, reducing damage to settlements situated behind them. They also affect wave and erosion patterns and can prevent loss of land. In some countries in Asia, such as Sri Lanka, coastal erosion is a big problem, with metres of land being lost each year. Although some of this erosion is a part of natural processes, bad coastal management and the loss of ecosystems can contribute to greater levels of erosion.

Ecosystems are also working invisibly all the time to support essential environmental functions from which we all benefit. Wetlands, such as salt marshes, help in flood control, soaking up water that might otherwise damage buildings in towns and villages. They help to trap and process pollution and nutrients that could otherwise be harmful to the surrounding environment. Trees and plants found in coastal ecosystems convert energy from the Sun by using photosynthesis, and in doing so remove carbon from the atmosphere and provide us with oxygen. This helps to regulate the climate and possibly assists in mitigating factors causing global warming.

3.2. Common livelihood activities in the coastal zone

Many people across Asia depend on coastal and marine ecosystems for their livelihoods. As these ecosystems have historically been highly productive with abundant resources, coastal communities have been able to take advantage of the livelihood opportunities that these present. This can be very important for poor people in particular, who are more likely to depend upon the "free" resources that can be gathered from ecosystems.

Fishing is one of the most common jobs that we associate with people's use of coastal and marine ecosystems. Fishing provides jobs and food for millions of people across Asia as well as supporting the economy of countries nationally (e.g., the fisheries sector provides income for 20 per cent of the population in Maldives). There are many forms of fishing and types of fishing gear or techniques, from large boats that spend many days out on the ocean catching metric tons of fish, to individuals fishing from the coast using lines, spears, harpoons or even scuba-diving gear. Although the usual image of a fisher is a man, there are many other people involved in the fishing industry that we do not often think about. Women often engage in activities such as gleaning, or collecting various marine organisms such as shellfish and crabs from inter-tidal areas at low tide; in some communities, women also fish. Many are involved in processing and selling fish once the catches reach the shore, and many more people depend on these resources for food.

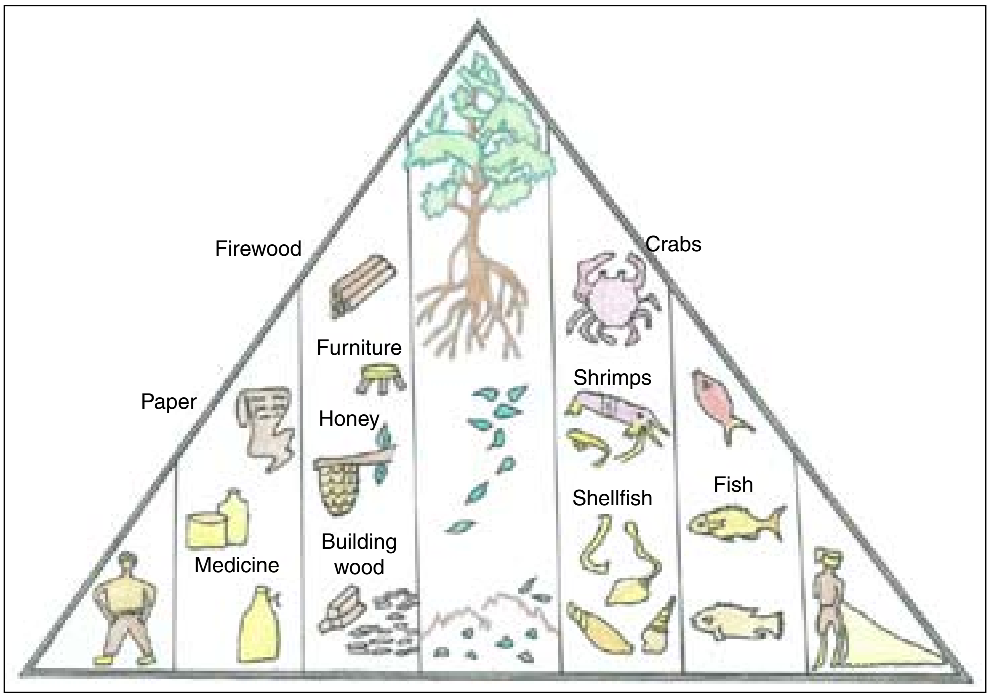

Figure 3.1. Goods that can be obtained from a mangrove ecosystem

Drawn by *H. Kanvinde and B. Begum.*

Mangrove ecosystems provide different resources for coastal communities. In addition to fisheries, mangrove trees are important for their wood, which can be used as fuel for cooking fires or for furniture and boat-building. Beekeepers who keep their hives in mangrove forests produce high-quality honey that can be sold for a good price. Certain mangrove fruits and seeds can even be used for food, and certain mangrove products are used in traditional medicine. Figure 3.1 illustrates the range of benefits that can be obtained from a mangrove ecosystem.

Just as farmers on land cultivate crops, there are a number of coastal and marine species that can be “cultivated”. This type of activity is usually referred to as aquaculture. Shrimp farms are very common across Asia, as are farms for certain fish species. Other common organisms used for aquaculture include oysters and algae. Aquacultural activities can contribute greatly to the local and national economies of countries in Asia, and, as nearshore fisheries become less profitable due to decreasing fish stocks, more countries are increasingly investing in aquacultural development.

In addition to the attraction of the benefits from the direct exploitation of coastal and marine resources, it is important to remember the other reasons that draw people to our coastlines. Big cities often grow around important ports, which allow goods to be exported and imported from other parts of the country or even other parts of the world. People are drawn to coastal areas because of the opportunities that they provide as a result of their natural resources as well as economically through commerce. As a consequence, some of the most economically and politically important cities in the region are in coastal areas (e.g., Chennai, Colombo, Jakarta, Karachi, Male’, Manila, Mumbai and Singapore).

3.3. Economic value of coastal and marine ecosystems

The goods (e.g., products) and services (e.g., environmental functions) provided by coastal and marine ecosystems are often seen as “free” for society. However, if we were to replace each one of those goods and services with an artificial alternative, can you imagine what the cost would be? If a wetland area acts as a sponge for flood waters and this is taken away, a community would have to invest a lot of money in developing flood management systems. If a coral reef prevents waves from eroding the coastline by acting as an offshore buffer and this is taken away, a community may have to build expensive sea walls or other structures to try to stop land erosion. If a mangrove forest provides fuelwood for nearby poor communities and this is removed, the people in that community may have to purchase kerosene or other fuels as a replacement. Coastal and marine ecosystems have a high economic value that we rarely stop to think about.

Just as coastal and marine ecosystems can be very important to people at the local or village level, it is also important to remember that the economic value of coastal and marine ecosystems at the country level can be equally high. Many countries in Asia are highly dependent on tourism as an economic activity while others are dependent on fisheries for export. Both activities could not be successful without healthy, functioning coastal and marine ecosystems. In Maldives, for example, tourism and fisheries are the two most important economic activities in the whole country, making up more than 40 per cent of the gross domestic product (GDP) and most of the foreign exchange earnings, and employing thousands of people directly or indirectly

Tourism is the movement of people who travel for leisure. Coasts and islands in Asia, with their long stretches of white sand and blue waters, attract tourists from all over the globe. Coral reefs, with their colourful marine life, attract both beach tourists and scuba divers. The good side of tourism is that it brings in money, creates local employment and adds a non-extractive value to coastal and marine resources. Tourists, especially dive tourists, come to see healthy, good quality coastal and marine environments, and they are willing to spend a great deal of money in order to do this.

Fishing can be carried out at the local level, and fisheries products can be used within communities or sold in local and national markets. With the advances in technology and greater access due to better road, sea and air transport, markets for fish can now be accessed further inland and even internationally. Bigger, mechanised boats and trawlers are now commonly used, catching more fish than ever before. Refrigerated vehicles, ships and aircraft can transport the fish in a fresh condition to any place in the world. Today, fish caught near your coastline may be consumed by someone in Japan, North America or Europe. However, this also places exceptional pressure on the resources, and the growth of the fishing industry has led to significant over-exploitation. Many fisheries are now not as productive as they once were, which means that, with time, the economic benefits they provide will decline. A well-managed fishery could sustain incomes and livelihoods into the future, but current trends are likely to force many people to seek other means of earning a living.

The wise management of coastal and marine ecosystems can result in huge benefits to broader society for the long term. Current economic systems do not always recognise this fact, and activities that produce benefits for only a few people for a short period of time are often supported over more sustainable management. It is important that more governments in Asia move towards understanding the economic value of these ecosystems in the future.

3.4. Cultural value of coastal and marine ecosystems

We have looked at how coastal and marine ecosystems are important and economically valuable for the goods and services they provide. Just as importantly, it should be remembered that communities often have a cultural or spiritual connection to these ecosystems. As many communities define themselves in relation to their local environment and livelihoods (e.g., fishing communities), these ecosystems become a part of day-to-day life and are incorporated in their traditions, stories and leisure. Many people enjoy walking by the sea or being in places of natural beauty. If an ecosystem is seen as important by a community only for its cultural or traditional value this also needs to be recognised.

Figure 3.2. Fishers in India sharing their local knowledge
© G. Sriskanthan

Communities in coastal areas are often great sources of knowledge about coastal and marine ecosystems, and have many important skills. For example, a fisher near your local village or town may know many things about where different species can be found, how conditions can change with the seasons as well as have considerable knowledge about local changes in the coastline over time.

Indigenous and local communities often have their own names and classifications (or "taxonomy") for resources, places (particularly significant sites such as fishing grounds), and natural resource-related activities. The ways in which these items are classified may not reflect the scientific classifications familiar to biologists; for example, criteria such as how edible or tasty different species are as well as seasonal availability may be used to categorise resources. Local or traditional knowledge is generally passed on by word of mouth through generations and often is not recorded in writing. For example, knowledgeable elders in coastal communities of the Indus delta in Pakistan engage in periodic gatherings with younger community members in order to share their experiences in connection with local fishing practices, grounds and seasons.

3.5. Suggested activities

(a) Our history and geography

Purpose: Local history is rarely incorporated in school curricula. When students interact with village or town elders to discuss the history of their own locality, they get a sense of value about their own island or village and the people that reside in them. The feeling of ownership of this historical heritage leads to greater self-esteem for both the child and the elder, and helps keep local knowledge, history and traditions alive. Understanding local history may make a significant change in the teachers' and students' thoughts about their surroundings, and it will provide a useful exercise for helping students to learn more about their local environment.

Equipment: Each student should carry a notebook and pen to make notes. Art materials depending on the outputs (see below for suggested outputs).

Activity: This activity will facilitate children's interaction with elders in their community when collecting notable stories related to local coastal and marine ecosystems. Before carrying out the activity with the students, the teachers should meet local knowledgeable elders to explain the purpose of the field trip and to set a time for them to meet with the students. Prepare the students by asking them to write down 3-5 questions that they would like to ask before the meeting. During the meeting, students can be asked to gather a few stories of local historical significance, e.g., an innovative boat builder or fisher.

Suggested outputs: The students can relate their discoveries by writing the stories they have collected in prose or as poems, or they can be encouraged to relate the stories in a more creative way, e.g., as a short, one-act play or a puppet show. These can be presented as single or group projects. Teachers can help the students to draw a time line of their village with significant local events; examples could include:

- Development: For example, when the first harbour or jetty, airstrip or large school was built in the village;
- Disasters: For example, cyclones, floods or tsunamis;
- Gradual changes: For example, changes in fishing practices or the introduction of new technologies.

Students can produce maps showing where the local craftsmen and fishers go to harvest resources from coastal and marine ecosystems. Use local terminology and names when labelling significant sites such as different fishing grounds and important resource harvesting places. Once prepared, these maps could be used as a baseline to conduct future studies. Students could update the map every six months or annually, and note any changes that they have observed.

All paper-based outputs can be displayed at a prominent place in the school or in public libraries. Local historians, museum workers, information officers or knowledgeable persons can be invited to the class to review the students' findings and encourage their efforts.

(b) Understanding local traditional economies (e.g., people who depend on subsistence fishing, gleaning and agriculture)

Purpose: To get students to actively think about the different kind of local livelihood activities in their community that are dependent on coastal and marine ecosystems.

Equipment: The children must carry a notebook, pencil, colour pencils, camera and a map of the locality. If a camera is not available, students could make a sketch of the person they are interviewing. If a map is not available, ask the person they are interviewing to assist the children in preparing a map showing sites of interest. Use a worksheet to enter interview findings (see example worksheet below).

Activity: Identify an expert (e.g., carpenters, boat builder, artisans, fishers, gleaners or octopus collectors) and fix an appointment so that the children can visit and interview that expert. If the children are of mixed age groups, divide them into smaller groups of mixed ages and have them interview the various experts.

The following example worksheet has been developed for interviewing a fisher. This can be used as a template for the exercise, but do not be limited by this example; include your own ideas, depending on the local circumstances. Develop similar questions for interviewing people with other ecosystem-related occupations.

Example worksheet: Local occupations – fishing

Name________________________________ Age________________________________

Address______________________________ Phone number_________________________

1. At what age did you start fishing? How did you get started?
2. What species do you catch?
3. Do you fish alone or with a team?
4. What gear do you need?
5. Approximately what is the size and weight of the catch?
6. Where do you fish? Mark the place on a map
7. How far offshore did you go today? How far did you go when you were younger?
8. How do you know the best places to fish?
9. How do you share the catch?
10. How do you process your catch?
11. Where do you sell your catch? Who helps you in the family?
12. Does fishing bring you enough income to support your family?
13. What special skills must a person have to take up this activity as a career?
14. Would you recommend this job for young people starting out?
15. What has been your most exciting experience when out at sea?

Suggestions for classroom work after the interview:

1. Write up your findings as a story told by the fisher/carpenter/boat builder etc.
2. Draw a resource/activity map to show where the people obtain their resources.
3. Draw a seasonal calendar to show annual activities.
4. Where does the catch go? Make a flow diagram to understand the market demand and supply chain.
5. Create a diagram of the energy relationships of the subsistence fishers and the ecosystem they depend on.
6. Describe the status of their favourite fishing location.
7. Compare the information gathered with what you learnt during your field trip excursions to local ecosystems.

4. Human interactions with coastal and marine ecosystems

This section looks at some of the conservation and management issues facing coastal and marine ecosystems in Asia, and explores the concepts of sustainable and unsustainable use.

Specific objectives

After completing this section, the student will be able to:

1. Name some of the main threats that coastal and marine ecosystems currently face;
2. Understand the connection between land-based activities and their impact on coastal and marine ecosystems;
3. Discuss sustainable versus unsustainable uses of coastal and marine ecosystems;
4. Understand local issues, and consider current and future changes in resource use;
5. Have a basic understanding of what constitutes the sustainable management of coastal and marine ecosystems, and what can be done to support this management.

As the previous chapter shows, human beings and coastal and marine ecosystems have had a long association. Since time immemorial people have understood the value of the goods and services provided by these ecosystems, and have used them to support their livelihoods. However, ecosystems are increasingly threatened by human activity due to unsustainable patterns of use and development. For example, in many parts of the world the number of fish in coral reef areas are now a fraction of what they used to be, and many species no longer exist locally, and sometimes even globally – this is what is referred to as "extinction". In other places, seagrass beds have been lost and mangrove forests depleted of trees. If changes are not made in the way we manage these ecosystems, there is a possibility that many of them could be lost forever – along with the products and services we have come to rely on.

There are a number of different reasons why coastal and marine ecosystems are threatened: direct exploitation (e.g., the clearance of ecosystems to make way for other types of land use, such as aquaculture in mangroves); the indirect negative effects of human activities (e.g., pollution); and even the impact of global phenomena such as climate change. Often, it is a combination of these different factors that contribute to the destruction of an ecosystem. Previous sections of this book show how different species are linked and interdependent, connected by their associations in the food web. Because of this, when certain species are removed or negatively affected, other species are also affected. When an ecosystem is threatened, this means that the way that the ecosystem functions; in other words, all the different organisms and their interactions that maintain the system are under threat. For example, a mangrove ecosystem that has had the majority of its trees removed will no longer produce leaf litter to feed the organisms living in the water beneath the trees. Without these organisms, larger animals will have nothing to feed on. Without the cover of the trees, the juvenile fish that live in the mangroves will no longer have protection or food. Without the small fish, the birds that come to the mangrove will have no source of food. Without trees and roots, the ecosystem will not be able to trap sediment, leading to increased erosion.

Coastal and marine ecosystems are able to replenish themselves up to a certain level. For example, if only a few trees are cut down for boat-building every year, these will be replaced naturally. If only a few boatloads of fish are brought in every day for local markets, the remaining fish will reproduce and replace the ones that have been taken out. However, when we extract more than the ecosystem can replace, the ecosystem becomes weak and degraded, and may ultimately stop functioning.

In the sections below, all the different reasons why an ecosystem may become threatened, degraded or destroyed are explored.

4.1. Direct effects of human activities

Unsustainable resource use

Figure 4.1. Mangrove wood collection in the Indus delta, Pakistan
© J. Tamelander

Ecosystems such as mangroves and coral reefs are the source of many important products, such as fish and fuelwood, which are useful to human communities. Although humans have been using these ecosystems for centuries, relatively recent changes mean that there are now more people than ever depending on these resources for survival. Coastal areas are seeing ever-expanding populations, both from migration as well as high birth rates. It is possible that coastal areas in Asia will see up to a 25 per cent growth in population between 2000 and 2025, which translates into an increase of 325 million people.[1] This increase means that more people are vying for the same number of resources. For example, the over-harvesting of mangrove trees for fuelwood is a common problem that contributes to mangrove degradation, as seen in areas such as the Irrawaddy delta in Myanmar and the Indus delta in Pakistan (figure 4.1). Poor coastal dwellers with limited access to alternative sustainable fuel sources are forced to cut fuelwood in order to cook and boil water.

Thus it is clear that increasing numbers of people depending on the same resources can put stress on ecosystems. However, sometimes a greater threat comes from the move towards more intensive extraction and the use of damaging methods of extraction (e.g., over-extraction of fuelwood, dynamite fishing, the use of poisons for fishing and trawling). With the introduction of new technology, people have been able to extract more resources with less labour, often to supply new, and more demanding, markets for coastal and marine products.

The fisheries sector is a good example of how over-exploitation damages the food web and the balance of the ecosystem. Through the introduction of technology such as scuba-diving, and because of more and larger fishing boats with engines and bigger nets that catch more fish than before, many species are now over-exploited, including many fish, lobsters and crabs, and sea cucumbers. In some fisheries, this has led to the crash of entire ecosystems.

The demand for greater amounts of fish may come from new markets, such as those in capital cities, inland areas or richer countries in Europe, North America and East Asia. As more countries develop economically, they become powerful demand markets that drive increasingly unsustainable fishing activities in countries in other parts of the world, such as in Asia. Local fishers with small boats may have an impact on coral reef ecosystems and fish stocks; but as long as there are not too many of them, and the fishing methods that they use are not destructive, the impact may not be significant. Large trawling boats (i.e., vessels that drag a large net behind them that scoops up everything in its path), on the other hand, are often more damaging. A trawl may be pulled at mid-water level, or along the seabed, a form of fishing that removes large numbers of different species and also causes untold damage to the seabed itself (e.g., by breaking apart coral and disturbing soft sediment). Some practices are particularly damaging. For example, although banned in most countries, some fishers still use explosives to capture fish. This destroys fish as well as their habitat (e.g. coral reefs). It takes many years for these damaged areas to recover.

Sometimes species are not just directly exploited for food. Each year, thousands of small, colourful fish are taken from coral reef ecosystems to be sold to the aquarium trade. People in Europe and the Americas as well as within Asia like to keep these fish in aquarium tanks because they look beautiful. Some fish species have been

1 M. L. Schwartz, 2005, *Encyclopedia of Coastal Science*, Springer, 1211 pp.

driven close to extinction because of this trade, and coral pieces are also often traded for use in aquariums. As well as leading to the over-exploitation of species, the methods of collection used can be very damaging to other species and the surrounding ecosystem. Fishers supplying the aquarium trade often use highly destructive methods to capture fish, such as breaking up coral to access fish hiding in reef recesses and using poisons. Poisons are commonly used to stun fish, making it easier to catch them, but result in the incidental death of other plant and animal species. The collection of aquarium fish is common in several countries, such as Indonesia, Maldives, the Philippines and Sri Lanka.

Figure 4.2. The colourful anemone fish is a popular aquarium species © S. Turek.

Another damaging form of direct, extractive use is coral mining, which involves removing blocks of coral from the sea and burning them in wood-fired kilns to produce a kind of cement for building. Much of Sri Lanka's coral reefs have been damaged or destroyed due to this, and it is also responsible for over harvesting of firewood in some areas.

Land conversion

There is an ever-increasing demand for land in coastal areas. As coastal populations increase so does the demand for housing; growing cities require land for business and industrial development and a booming tourist economy means that coastal areas are developed to accommodate visitors. In addition, increasing numbers of people come with increasing amounts of waste that needs to be disposed of somewhere. Often, in the face of all these development pressures, coastal and marine ecosystems are cleared or converted for other uses. For example, wetlands may not be perceived as valuable because people are unaware of the vital role that such areas play in regulating the environment and controlling events such as flooding. Instead, they are viewed as wastelands that are of little use, and are often cleared to make way for other types of land use. Sometimes they are simply converted into garbage dumps. For example, in many parts of Sri Lanka, including the capital, Colombo, marshy areas and wetlands are used for garbage dumping, causing environmental and health hazards.

The destruction of mangroves for coastal development and aquaculture is a common problem throughout Asia. The Chokoria Sundarbans mangrove area in south-east Bangladesh previously covered 75,000 ha, but it has been reduced to less than 1,000 ha. This is due to a number of reasons, including the over-exploitation of mangrove resources, and the use of mangrove land for cattle grazing and salt production. One of the main reasons for the loss of so much mangrove area has been clearance in order to set up shrimp ponds for the aquaculture industry. This is a pattern that has been repeated in many mangrove areas across Asia and the rest of the world, and it is one of the major threats to this ecosystem. However, there are examples of more environmentally sound aquaculture practices near mangrove areas, as seen in Viet Nam.

4.2. Indirect effects of human activities

Pollution

Pollution and the improper disposal of waste is a common problem in coastal areas. Villages and towns can produce large quantities of domestic and industrial waste, and many countries in Asia do not have proper systems for ensuring that this is disposed of in an environmentally friendly way. When walking along the shore, it is likely that you will see many things washed up that originate from human activities: plastic bags, shoes, packaging for food or plastic bottles. Every year, tons of non-biodegradable waste is thrown away in such a manner that it makes its way to the sea, or is dumped in coastal areas.

Wetlands, including mangroves and salt marshes, are commonly used as areas for waste disposal because they are seen as land that has no useful purpose; this rubbish smothers the plant life, thus changing the environmental conditions and leading to ecosystem degradation. Rubbish that washes up on coral reefs can smother the delicate coral polyps as well as other plants and animals, damaging these fragile ecosystems. Waste in the open ocean is also responsible for the death of many marine creatures each year. Marine turtles may mistake plastic bags for jellyfish and eat them, killing these endangered creatures. Strips of plastic and string in the open ocean or in coastal areas can become entangled around the legs or beaks of birds and result in their death.

Sometimes coastal and marine ecosystems are affected by other kinds of waste such as sewage, chemicals or fertilisers that are washed into coastal areas. These pollutants may originate many kilometres inland. For example, fertilisers used in upland farming areas are flushed into rivers after rainstorms, and make their way down to the coast. Nutrient pollution, called "eutrophication", occurs when the amount of nutrient-rich compounds, such as nitrate and phosphate that are common in fertilisers and sewage, increases above natural levels. These nutrients cause a rapid increase or "bloom" of certain types of plants and algae, which smothers other organisms and prevents light from reaching them. This also creates a lot of dead organic material, which, when it decomposes, consumes all the available oxygen and results in the deaths of aquatic organisms. If severe, eutrophication can result in the destruction of an entire ecosystem. There are also other pollutants that can poison animals and plants as well as cause changes in the chemical balance of sensitive ecosystems. Many industrial wastes that are discharged directly into marine areas can be highly toxic and lead to poisoning of organisms.

Alien invasive species

In the previous chapters we have looked at how all the different organisms in an ecosystem interact, and have seen that the ability of an ecosystem to function properly is largely supported by the sum of these different interactions. Most ecosystems have changed slowly over thousands or even millions of years; the species in an ecosystem have accordingly evolved over time to suit their surroundings and their relationships with one another. Humans have been moving plants and animals around the world for the last few hundred years. Sometimes these introductions can be deliberate (in the case of fish species that are introduced to different countries to be used in fish farms), or accidental (in the case of marine creatures transported by ships, either attached to the hull or contained in the ballast water). If a plant or animal from one ecosystem is introduced into another ecosystem that has never been exposed to this non-native species, this can have very damaging effects. Sometimes these "new" species may out-compete or predate on resident species in the host ecosystem. These non-native species, which are damaging to the host ecosystem, are often referred to as "alien invasive species".

An example of an alien invasive species that has had a negative impact on native ecosystems is the European green crab, *Carcinus maenas*. Native to western Europe, the European green crab is thought to have made its way to other parts of the world accidentally via ballast water in ships as well as through accidentally being transported with other commercially-traded marine species. The European green crab is now found in the United States, South Australia and South Africa, where it has been seen to successfully reproduce and prey upon bivalves such as oysters and clams, causing huge declines in the populations of the latter. As clams and oysters are economically very important to people who make their livelihoods through selling them, the European green crab has had a huge impact on the clam industry in some parts of the world. As we can see in this case, invasive species can be extremely damaging to human economies as well as ecosystems.

Examples of coastal alien invasive species in Asia include the "prickly pear" cactus, *Opuntia dillenni*, which was introduced from the Americas. In coastal areas of Sri Lanka, the prickly pear has become a huge problem as it spreads rapidly in coastal areas, dominating the native vegetation and pushing it out.

Figure 4.3. Prickly pear growing on the coastline of Sri Lanka
© C. Bambaradeniya

4.3. Global climate change

Global climate change is a threat to ecosystems the world over, on land as well as in coastal and marine areas. The earth has been experiencing a gradual increase in average air temperatures for much of the twentieth century. This is now known to be caused mainly by human activities that have led to greater amounts of heat-trapping gases, or “greenhouse gases” being released into the atmosphere. The burning of fossil fuels, such as petrol for cars and coal for powering homes and power-generating plants, results in the release of carbon dioxide. Carbon dioxide is the most common greenhouse gas, although other gases such as methane have also increased in the Earth’s atmosphere due to human activities.

Sea-level rise

As the earth’s average temperature increases, ecosystems around the world are increasingly affected. One of the most dramatic changes is the gradual rise in the Earth’s sea-level. Rising temperatures are melting the polar ice caps, the large bodies of ice in the north and south polar regions, releasing more water into the sea. As the sea warms, the water itself also expands, adding further to sea-level rise.

Rising sea-levels will result in coastal areas and low-lying land being inundated and even lost. The islands of Maldives and the Union Territory of Lakshadweep in India, for example, have an average height of 1 metre above sea-level. Even a small increase in the height of the sea would result in increased shoreline erosion and the loss of much of the land in those areas.

Extreme weather events

Climate change will also lead to shifts in global weather patterns. It has been predicted that weather patterns will become more extreme. Some areas may experience more drought, while others may suffer more flooding. It is also thought that extreme weather events such as hurricanes, cyclones and tropical storms may become stronger and increase in frequency. Extreme weather events can be very damaging to coastal and marine ecosystems. Ecosystems can act as buffers, preventing damage from strong winds or waves by presenting a physical barrier that protects human settlements. However, in acting as a buffer these ecosystems also suffer damage. Cyclones and hurricanes in countries such as Bangladesh or Myanmar, for example, have been seen to result in the destruction of large areas of mangrove ecosystems by uprooting and killing trees. Ecosystems are able to regenerate and recover from extreme events; however, if the damage is too severe or the events happen too frequently, the ecosystem will not be able to recover. In addition, if the ecosystems are already weakened due to direct exploitation and indirect damage from human activities, they will also be less likely to recover effectively.

Surface sea temperature changes

Increases in air and sea temperatures will also have a huge impact on coastal and marine ecosystems. For example, coral reefs and their associated communities can only tolerate narrow ranges of sea surface temperatures. Coral polyps, when exposed to higher temperatures, eject the algae (zooxanthellae) that help them produce food, causing them to die. When corals do this, they become white in colour – a phenomenon called “coral bleaching”. Increases in sea surface temperatures during an El Niño weather event in 1998, for example, led to the most widespread coral bleaching and mortality ever recorded, and was particularly severe in the Indian Ocean. Because of climate change, it is possible that the world will witness the destruction of many coral reef ecosystems, and the loss of the fish and other animals that depend on them, in the next few decades.

Finally, more carbon dioxide in the air also leads to more carbon dioxide in the water, which affects chemical and physical processes in the ocean. This includes an increase in the acidity of seawater (a reduction in the pH value), which in turn reduces the amount of material available for organisms that make their shells or skeletons from calcium carbonate, such as corals. This will make it increasingly difficult for organisms to build skeletons and grow, and many may not be able to cope with the changes.

4.4. Suggested activities

(a) Ecological footprint

Purpose: The ecological footprint refers to the direct, negative impact that all the activities and patterns of consumption by people (or even a business, town or country) have on the environment. The aim of this activity is to get students to think about how different activities – as well as they themselves – have an impact on the environment, and how changes in behaviour can reduce an ecological footprint.

Background: The concept of the ecological footprint is an attempt to measure human demand on the Earth's ecosystem and natural resources. It compares human consumption of natural resources with the planet's ecological capacity to regenerate them, by estimating the amount of biologically productive land and sea area needed to regenerate (if possible) the resources that a human population consumes, and to absorb and render harmless the corresponding waste. The smaller the ecological footprint, the better it is for our environment.

The students can be introduced to the concept of ecological footprint by looking at common activities in their community. Look at two comparable activities: one with a relatively low ecological footprint and one that has a higher ecological footprint. Then start tracing the different components that go towards that activity, such as the origin of different materials and the processes by which the material has reached its destination point. Consider energy and material requirements of how the material for each activity is made, stored, packaged and transported, the waste produced as a result, and the impact on our environment. Teachers should try out this exercise before explaining the concept to the students. At the end, the student should realise that it may be wiser, from an environmental point of view, to engage in low energy intensive activities such as consuming locally grown food.

Activity: First explain the concept of ecological footprint to the class. Get the students to identify two activities that are similar, but where one is more sustainable than the other. Examples include:

More sustainable activity	Less sustainable activity
Using a sailing boat for fishing	Using a motorised, fibreglass boat for fishing
Drinking king coconut water	Drinking a bottle of coke
Transport by bicycle	Transport by motorcycle

Ask the students to form groups of 5-10 and brainstorm about the physical resources that would be required for either of the activities, and to compare how much greater the ecological footprint of one activity is compared to another. Get them to list all the component resources that contribute to each activity. Remind them to think about the scale of energy use. For example, a motorised boat requires petrol for each operation, whereas for a sailing boat petrol is only used to transport the component parts of the boat while it is being built: a one-off use of a non-renewable resource. This makes the ecological footprint of the sailing boat lower.

A more detailed example, which compares the ecological footprint of using a sailing boat and a motorised boat for fishing, is given below. This is not a complete list of all the resources that could be used, but gives an idea of the differences in energy and resource use, and the relative ecological footprints of each activity. The idea is not to accurately calculate how much energy is used in each activity, but rather to give the students an idea of how much more energy and material intensive one activity may be, compared to another.

Using a wooden sail boat for fishing	Using a motorised fibre glass boat for fishing
Wood for the boat from a forest in a nearby province transported by truck: • Wood; • Petrol to run the truck, • Metal and rubber for the truck's body and tyres; • Limited one-off burning of fossil fuels for transport. Pole for the sail harvested from the local mangrove wood: • Energy and resources used in metal production for the knife used to cut the pole down; • Plastic on the handle of the knife that comes from petroleum. Cloth for the sail made of cotton as well as synthetic rope, transported from another part of the country by truck: • Growing the cotton – fertilisers, farm machinery, fuel, packaging, pesticides; • Weaving machinery made of metal, rubber, other petroleum-based products; energy used to run the machinery; • Truck – petrol, metal for truck's body, rubber for the truck tyres, other petroleum products; • Rope – petroleum products, energy; • Limited one-off carbon emission due to burning of fossil fuels for transport). Nails used to make hull of boat: • Energy and resources used in metal production.	Fibreglass hull from China, transported by a large ship: • Fibreglass – plastic and other petroleum products; • Shipping – steel ship body, petroleum, plastic, other petroleum products (e.g., oils); chemicals used on the ship's hull; • Large amount of carbon emission due to burning of fossil fuels for transport. Fuel for the boat: • Petrol; • Transport of petrol from the Middle East by tanker – materials used for tanker (metal, plastics and other petroleum products); refining of petrol – large amount of carbon emissions for refining the petrol, materials used for refinery (metal, plastics and other petroleum products); • Daily carbon emissions due to burning of fossil fuels used in petrol for boat. Engine made in nearby city: • Energy and resources used in metal production; • Petroleum in oils needed for operation; rubber parts from rubber plantation in another country and transportation of those products. Glues used in sealant for boat: • Toxic petrochemicals used in glue production; • Waste products from glue making process in factory.

(b) Measuring human impact walk

Purpose: To allow students to explore the types of human activities that may have an impact on coastal and marine ecosystems in their locality through direct observation.

Equipment: Each student should carry a notebook and pen to make notes.

Activity: Take a group of children for a one- to two-hour walk along the beach, e.g., near a coral reef or seagrass bed, or near a mangrove forest. During the walk, the children should be asked to observe and note down all the human activities they come across. What kind of activities were people involved in? The activities could range from fishing to construction, selling souvenirs or dumping rubbish. If they were fishing, what kind of gear was used? If they were involved in recreational activities, what were they (walking, swimming, water sports, picnicking etc.)?

On returning to the classroom, the children can be encouraged to discuss the activities they observed, which activities were most frequently observed, and what implications each activity could have for the coastal and marine ecosystems nearby.

(c) Waste walk

Purpose: To get students to think about waste disposal and management, the implications of non-biodegradable waste for the environment, as well as how waste affects local ecosystems. This activity can be carried out in conjunction with another excursion-based activity, or as part of a school coastal clean-up day (see section 5.2).

Equipment: Each student should carry a notebook and pen to make notes, and be given a large plastic bag (e.g., a garbage bag) with which to collect rubbish.

Activity: Take a group of children for a one- to two-hour walk along the beach, e.g., near a coral reef or seagrass bed, or near a mangrove forest. During the trip, the children should be asked to collect any waste or rubbish originating from humans that they find, and to keep this in the plastic bag.

Figure 4.4. Items collected during a waste walk by students in India

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Once back in the classroom, the students should review all the items they have collected, and classify them in terms of the material they are made of (e.g., wood, cloth, plastic, rubber etc.). Using the table below, the students should identify the estimated time it takes for each type of waste to biodegrade. To present their findings, make a chart of what the students gathered and the time it takes for these items to degrade. Hold a discussion with the students on the different methods of waste disposal and introduce the concept of recycling, using the following discussion guidance ideas:

- Ask the students to categorise various items according to the environmental consequences of their production, use and subsequent disposal (e.g., how much energy does it take to make the item? What impact(s) does it have on the ecosystem during its use? How long does it take to biodegrade and what negative impacts can it have on the environment as garbage?);
- Ask students to make a map of the geographic connections between us, the users of these items, the places on the planet where resources came from for making the items as well as where environmental impacts might be seen;
- Have the groups share their findings, using the map to show connections;

- Using the list of the environmental consequences of each item, discuss alternative ways of making, using, disposing of, or replacing the items that would have a smaller environmental impact. Make sure to end on a positive and hopeful note – we can all help by doing the best we can in searching for more creative solutions to sustainable living;
- Conclude with a review of the lesson and ask students to explain how they can make a difference in their personal lives to reduce their ecological footprint.

Estimated times for various common waste items and materials to biodegrade

Garbage item	Approximate time taken to decay/biodegrade
Paper towel	2-4 weeks
Apple core	2 months
Cotton rag	1-5 months
Paper	1-5 months
Rope	3-24 months
Orange peel	6 months
Dead animal	Less than 1 year
Woolen sock	1 year
Plywood	1-3 years
Cigarette butts	1-12 years
Milk cartons	5 years
Painted wood	13 years
Plastic bag	10-50 years
Plastic bottle	50-80 years
Rubber sandals/flip-flops	75 years
Tin can	50-100 years
Disposable diapers	200 years
Aluminium can	200-500 years
Styrofoam cup	500 years
Plastic six-pack rings	500 years
Fishing line	600 years
Glass bottle	1 million years

(d) Visit to a tourist resort – how eco-friendly are our resorts?

Purpose: To understand the impact of tourism on the environment and to get students to think about how tourism can be made more environmentally friendly.

Equipment: Each student should carry a notebook and pen to make notes. Groups that will be drawing maps should carry 2-4 large sheets of drawing paper and coloured pencils/crayons/pens.

Activity: Choose a hotel or resort near the school. Get permission from the hotel to bring the students to conduct their study. Explain the activity carefully and check that it is permissible to talk to guests at the hotel.

Divide the children into three smaller groups.

- Group A will make observations of the hotel and its surroundings and draw a map.
- Group B will interview tourists, find out where they have come from, and note the three best and three worst experiences they have had on their trip.
- Group C will interview hotel staff about how the hotel uses energy and resources to assess how environmentally friendly it is.

The questions that they are going to ask should be decided before the trip and written down. Rate each on a scale of 1 to 5, 5 being awarded for the positive things that the resort is doing, and 1 being awarded for more environmentally damaging activities. Some examples are:

- The use of an “energy key” that allows the electricity to be turned on only when the guest places the room key in the switch;.
- The use of gas in place of electricity for cooking;
- The use of CFC-free refrigerators in the kitchens and the rooms;
- The use of solar panels for heating water and for outdoor lighting;
- The use of air-conditioning in rooms/cottages;
- The use of water-saving devices in toilets;
- Where food is purchased, and whether many imported goods are used;
- How sewage is processed – does the resort have its own sewage plant?
- How waste is processed, including plans to minimise waste, sorting, recycling, dumping etc.;
- Whether energy demanding activities, such as motorised water sports, are offered;
- Whether there are bright lights on the beach (if the resort is built near a turtle-nesting beach, light may prevent turtles from coming ashore to lay eggs);
- Is beach vegetation planted? Are native species used for this?
- Is scuba-diving/snorkelling controlled and does it take place at established sites?
- Does the hotel support local community projects?
- Does the hotel encourage guests to buy produce from self-help groups, women’s groups and local artisans?
- Does the hotel have a nature-interpretation centre to teach tourists about the nature and culture, and the “do’s and don’ts”?

Interpreting the results: Depending on the number of questions that are asked, calculate the maximum score possible (e.g., if 20 questions are asked, the maximum score would be 100). If the rating is close to the maximum rating possible, this shows that serious action is being taken to make the hotel environmentally friendly. Lower scores indicate that more can be done to improve operations.

Classroom work: Discuss the findings and ask each team to make a presentation of their findings. Encourage the students to carry out a similar audit in their own home to determine how environmentally friendly their domestic activities are. What areas could be improved? How easy is it to influence their family to do things differently? Compare the amount of energy and water they use with the amount the tourists use.

(e) Local geography and changes

Purpose: To get students to think about changes in their local community and environment, and to think about how future changes may affect the coastal and marine ecosystems.

Equipment: Resource map of the locality (either an established map or one that the students have developed). Notebooks, pens, colour pencils/crayons, drawing paper.

Activity: Ask the students to use a resource map of the locality as a discussion tool. As homework, get the students to discuss with their grandparents and parents about what the village/locality looked like when they were young/20 years ago, what services were available then, the size and type of buildings, the extent of the mangrove ecosystems, the type of roads that were available etc. Split the class into 3 or 4 smaller groups and get them to discuss their findings and compare these to their own lives today as well as visualise what it may be like 20 years from now! After the discussion, each group should paint a picture depicting life “yesterday”, “today” and “tomorrow”. Each group can present their paintings to the larger class, using them as a tool to explain their findings and discussions.

5. Management, conservation and restoration of coastal and marine ecosystems

This section provides an introduction to the main methods of coastal and marine ecosystem management and conservation. Current approaches are discussed in detail, including ecosystem restoration techniques.

Specific objectives

After completing this section the students will be able to:

1. Explain concepts of sustainable management;
2. Understand ownership and trusteeship of the coastal resources around them;
3. Be aware of different management and conservation methods;
4. List examples of conflicts within the coastal zone;
5. Suggest ways to resolve conflicts;
6. Appreciate the need to manage resources sustainably and protect the environment.

In the previous chapter, some of the destructive activities that damage coastal ecosystems were discussed. Damage to coastal ecosystems can be immediately visible, such as physical damage to forests and coral reefs. There are also less obvious, although equally severe impacts, such as over-fishing or the loss of species, which upset the balance of life through changing the food web. This chapter discusses the need to manage coastal and marine ecosystems and their resources, in order to maximise the benefits they provide while ensuring long-term sustainability. Conflict resolution, education and the roles of the individual and the government are discussed.

The need for management

Irresponsible and poorly planned use of coastal and marine resources can result in the long-term decline of those resources. As a result, human communities are affected and future generations may not be able to benefit from these ecosystems. When the environment or a resource is managed in a way that results in its continuing degradation or decline, it is called unsustainable use. Wise coastal and marine resource management should ensure development and exploitation are sustainable while seeking to maximise social and economic benefits that are distributed equitably among communities and other user groups.

Users, or “stakeholders”, that depend on, or interact with, coastal and marine resources are diverse; fishers, mangrove cutters, shell collectors, reef gleaners, seaweed farmers, fish farmers, hotel developers, municipal authorities, harbours and shipping companies are but a few examples. Each one of these stakeholders has their own goals or interests in the management and use of coastal and marine ecosystems. Conflicts may arise between stakeholders when resource use either overlaps or has an impact on one or more of the others. Management is essential to reduce and redress user conflicts and unsustainable use of coastal resources.

5.1. Management approaches

Usually a country’s national government is responsible for the overall management of coastal and marine areas and resources within that country’s legal boundaries. Coastal management focuses on the “coastal zone”, i.e., ocean areas near the coastline as well as the area of land that has some influence (e.g., biological and physical influence) on the ocean.

Formal management of coastal areas and resources usually involves different government agencies overseeing development and resource-use activities in the coastal zone as well as regulating activities through laws and the enforcement of those laws. For example, a Fisheries Act and other fisheries-related legislation may ban harmful fishing practices and define what fishing activities are allowed, where and when. It may also set limits in terms of the amount of fish that can be taken (e.g., "quotas" for specific target species) and may include provisions for "licensing", which is used to limit the numbers of users of a certain gear or in a certain place. A "Fisheries Department" is often responsible for ensuring fisheries legislation is followed and management of fisheries. Similarly, a "Coast Development Authority" may be responsible for coastal development, including the regulation of what economic activities are allowed in what part of the coastal area. There is also legislation as well as corresponding institutions that will be involved with biodiversity conservation. Often protected areas, such as national parks or sanctuaries, are established and managed through these institutions.

Although each of these laws and agencies deal with slightly different aspects of use of coastal areas and resources, they are to some extent concerned with the same area of land and sea. One of the most important aspects in working towards sustainable management is to clearly define responsibilities and ensure proper co-ordination and collaboration between agencies. Another is to address issues of "ownership" among stakeholders. In the open sea, territory and resources are frequently not owned in the same way as on land. Anyone is free to use them as long as the use is in compliance with national, local and, in the case of international waters, international legislation. This is called an "open access" system. Because so many uses overlap or have an impact on each other, the risks for over-exploitation as well as conflict are particularly high.

Integrated Coastal Management

Because coastal areas are affected by the interactions between different ecosystems, different government departments and different user groups, an "integrated" approach is needed to ensure that all the different activities, goals and points of view are taken into consideration. Integration means bringing the many different parts together so that they can work together in a co-ordinated way. Integrated Coastal Management (ICM) is a form of land-use planning targeted at coastal areas, which provides the framework for management of the coastal and marine environment. ICM is also sometimes referred to as Integrated Coastal Zone Management (ICZM), Coastal Zone Management (CZM), Integrated Coastal Area Management (ICAM), or Integrated Coastal Area and River-Basin Management (ICARM). While slightly different in scope, these terms are all related to management approaches that are based on the same ideas and strive towards similar goals.

ICM is carried out with the help of co-ordinating bodies, which include representatives of all the relevant management authorities as well as stakeholder groups. Regular meetings for information exchange ensure that balanced decisions can be taken with the collaboration of all stakeholders when there is an issue that needs to be tackled. A few examples of the kind of issues that ICM management authorities may have to deal with are:

- Pollution or solid waste, e.g., from industrial sources or municipal dumps;
- Agricultural run-off that might cause nutrient enrichment and/or increased turbidity;
- Port development and coastal engineering, such as dredging and land reclamation;
- Mining in coastal areas or upstream of rivers that influence the coast;
- Establishment of conservation areas, such as national parks, in the coastal zone;
- Construction activities, whether industrial, urban, residential or tourism;
- Development in a river basin or watershed that may affect coastal waters, such as land clearance.

ICM is currently being developed throughout the Asia region. In most countries, the development of legislation requiring coastal States to prepare coastal management plans is relatively recent. In others, such as Sri Lanka, coastal management has been of concern since 1963. Local-level ICM activities are underway in many places in Asia, such as Bali (Indonesia), Chonburi (Thailand), Danang (Viet Nam) and Sihanoukville (Cambodia). There are also numerous district-level ICM initiatives throughout South Asia.

Traditional management

The formally-recognised methods of coastal and marine management outlined in this chapter are largely based on the role of state institutions. However, long before state institutions were established, many coastal communities had devised their own systems of management of marine and coastal resources. Where these systems of management still exist, they can be just as effective as formal methods of coastal and marine management.

In some places, traditional ownership of coastal and marine areas is informally recognised, and specific villages own clearly defined areas of sea, lagoon or coastal areas for fishing or other types of resource use. In addition to demarcated fishing zones, the village elders/leaders/religious heads may also define management decisions, such as types of fishing allowed, time of fishing, areas where mangrove products can be collected etc. Such systems of traditional management should ideally be incorporated into formal ICM and coastal management. However, traditional methods of management are not always recognised by national laws and have, partly because of this, been weakened in many areas; thus, they have not been able to cope with development and population increases in the recent past.

However, there are some instances where traditional management has been fully recognised by formal management systems. In Maldives, the Government has recognised the importance of traditional systems in providing fishing rights to specific islands, and has now incorporated these traditional rights into a fisheries law. Some fishing communities in Pakistan have introduced gear and size restrictions in order to promote sustainable management of fisheries. In addition to marine fisheries, traditional community knowledge and management is widely applied in inland and estuarine fisheries throughout Asia. Some of the best studied examples in community-based fisheries management are of the ox-bow lakes in Bangladesh where communities are given ownership and responsibility to manage fisheries.

Economic Exclusion Zones

Countries with a coastline may claim an Economic Exclusion Zone (EEZ), stretching 200 miles out to the sea, which is internationally recognised as being part of the country's territory. The EEZs of most countries are very important for fisheries and other marine resources. A government may allow other countries to use its EEZ for defined purposes, such as fisheries. This is usually done using a permit system whereby a fee has to be paid in order to access the host country's EEZ. For example, permits can be granted for foreign vessels to fish in the national EEZ of countries in Asia. As global fish stocks are suffering from overexploitation, the challenge for the region's governments is to ensure that the resources of Asian nations' EEZs are wisely managed and that licences and quotas are not set in a way that leads to overexploitation of marine resources.

Marine resources in the international waters outside of EEZs can be used by any nation, but there are separate laws governing the use and management of these international waters. For example, quotas for commercially important fish are set through intergovernmental bodies.

Marine and Coastal Protected Areas

Areas that are seen to be ecologically important (e.g., critical to the survival of certain endangered plants or animals, very rich in biodiversity, representing unique habitats, or are important for fisheries or other resource uses) can be given special protected status that restricts how people can use these areas. Such areas are known as Protected Areas (PAs). The IUCN definition of a PA is: "A clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values".

PAs have been established for almost every type of ecosystem found in the world, from forests to deserts. PAs that have been developed for ecosystems in coastal and marine areas are known as Marine and Coastal Protected Areas (MCPAs), and sometimes referred to as Marine Protected Areas (MPAs).

MCPAs are usually designated and managed by a specific government authority, although in many countries several different departments may be involved. Each MCPA should have clear recognition, whether legal or otherwise, a management plan, a well-defined boundary and a clear understanding of permitted and non-permitted activities within the boundaries among all stakeholders. Activities are

Figure 5.1. Protected areas generally use signposts as a way of communicating protective measures to the public, such as this mangrove protected area in Sri Lanka

© G. Sriskanthan

implemented that work towards meeting the objectives set out in the management plan, including enforcement of regulations, and impact is measured through monitoring.

In order for MCPAs to work successfully, local communities must be included in the management process, be fully informed, accept any restrictions, and should incorporate a well-supported management system to ensure community participation in MCPA management.

There are many problems with the management of MCPAs in Asia. Although many MCPAs have been designated by governments and exist on "paper", management "on the ground" is often weak, and thus MCPAs fail to achieve their objectives. There are many reasons for this, including: a lack of government human or financial resources to manage these areas; poor enforcement and lack of support from enforcement authorities; lack of proper participation by local communities due to poor management design and failure to include people effectively; and corruption.

5.2. Other conservation and management activities

The management processes and tools described in previous sections have been developed to support good management on a broad scale. There are also a number of more specific conservation and management activities that can be carried out to address particular problems, often as part of a broader management system. Some of the more common activities are described below.

Species protection

Just as important ecosystems can be specially managed under protected areas, important species that are threatened can be specially protected. Most countries have wildlife regulations that have been developed to protect species that are threatened, and often those regulations are supported internationally through treaties or conventions. Marine turtles, for example, are considered to be endangered, and all the known species of marine turtle are protected under international and national laws across Asia. Such laws prohibit the slaughter of marine turtles for food, in most cases prohibit egg collection, and place restrictions on how live turtles can be held in captivity. In addition to protecting individuals, important nesting and feeding areas can also be protected. The olive ridley turtle nesting sites in Orissa, India, are a good example. Certain development activities and fishing in nearshore areas are restricted during the nesting season to prevent disturbance of nesting females and to ensure that they are not accidently killed by the activities of fishing vessels. Nesting beaches themselves are specially protected and certain developments are restricted on important nesting beaches.

Figure 5.2. Marine turtles are protected by law, and many programmes target the protection of nests and hatchlings, such as this leatherback hatchling in Thailand

© G. Reib

Other species that are specially protected include dolphins, whales, dugongs, and several shorebirds and seabirds. Many other species, such as sea cucumbers, certain fish used for the marine aquarium trade and corals, are also protected by law in some countries in Asia. The IUCN Species Survival Commission maintains a "Red List" of threatened species, which is available online (www.iucnredlist.org/).

Beach and reef clean-ups

Beach and reef clean-up operations can be organised to remove solid waste that damages the ecosystem or disturbs activities. Along the shore this can be done very simply using groups of people to physically pick up garbage and then dispose of it in officially designated garbage dumps. Removing waste from reefs and other sub-tidal areas requires more specialised action, as snorkellers and scuba-divers may be required to remove items. Special instruction should be given to individuals involved in such clean-up activities, to ensure that further damage is not done to the reef. Beach clean-ups are a good activity that can be carried out by groups of students or even as an activity for the whole school to mark an environmental event, such as World Environment Day.

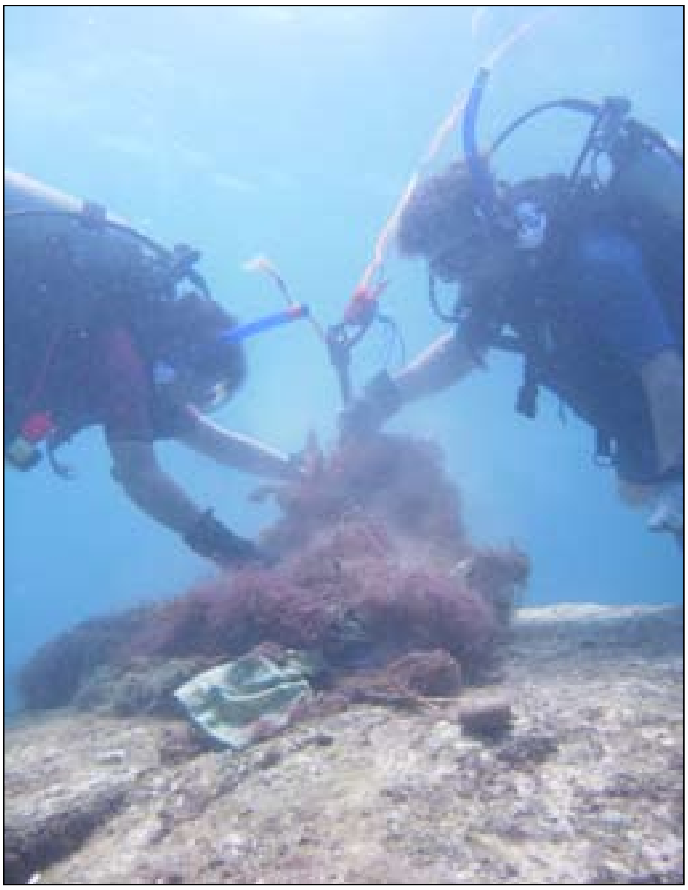

Figure 5.3. Debris from the 2004 Asian tsunami being removed from reef areas by volunteer divers in Sri Lanka
© M. Meynell

Removal of alien invasive species

The physical removal of alien invasive species from areas that become infested with them may be necessary. In the case of coastal species, such as the prickly pear cactus, this can be done with carefully instructed groups. When removing invasive plants, it is important to ensure that the entire root system is removed, and that the removed plants are properly destroyed after being taken out so that they are not able to take root again. Marine alien invasive species are often much more difficult to remove, and eradication campaigns, if attempted, should be planned and undertaken by specialists.

Zoos and aquariums

Zoos and aquariums can act as important conservation awareness tools as well as help to increase public understanding of, and interest in, coastal and marine species. Animals from a range of different ecosystems, including marine and coastal species, can be kept for public viewing. Special expertise is required for managing zoos and aquariums, and it is often both cost- and labour-intensive to manage zoos and aquaria well. Marine species, in particular, need to be kept in the correct conditions that mimic their natural environment, which requires advanced equipment for ensuring good water quality and temperature.

Some zoos and aquariums can be used to support the captive breeding of endangered species. Captive breeding of endangered species can be used to assist recovery of populations that have been severely decimated, by carefully reintroducing individuals bred in captivity back into the wild. For example, certain bird and mammal populations that have been affected by human activities have been strengthened through captive breeding programmes. However, this technique is often difficult and expensive, and can only be used with some species. As with all conservation measures, the removal of threats that affect endangered species must be removed in order for any other measures to be useful.

5.3. Restoration of coastal and marine ecosystems

Degradation and destruction of coastal and marine ecosystems can be prevented by good coastal and marine management efforts. However, there are many cases where management is lacking or insufficient or where damage has already been done. In some cases, restoration can be used to facilitate ecosystem recovery. However, it should be noted that coastal and marine ecosystems have developed over long periods, and it is very difficult to re-create these ecosystems in terms of their complexity and structure. Restoration is thus never the only solution to a problem, and should, where applied, be used to complement other management efforts.

Natural restoration
Coastal and nearshore marine ecosystems are affected by many natural shocks, e.g., cyclones, wave surges and storms, but also have the ability to recover naturally from such shocks. For example, the large mangroves of the Sundarbans in Bangladesh are periodically subjected to cyclones that result in physical damage (e.g., uprooted trees, broken branches and sediment dumping); however, in most cases the mangroves recover naturally after a cyclone, with the recovery time depending on the extent of the damage. Often, if there are not too many other pressures on an ecosystem, such as pollution or over-harvesting, ecosystems have the ability to recover without any assistance if given time and favourable conditions.

Allowing ecosystems to repair themselves naturally, where possible, is thought to be the best approach to supporting recovery. This is because any ecosystem regrowth allowed to occur naturally is more likely to be suited to the surrounding environment, more likely to survive in the long-term and more closely resemble natural species assemblages. To support natural recovery, it is important to focus on removing threats that negatively affect the rate of recovery. For example, reducing harvesting of mangrove timber in areas recovering from cyclone damage will facilitate more rapid and complete recovery. Reducing or removing the use of damaging fishing techniques can contribute to recovery of a fish stock and even an entire reef system.

Active restoration
Sometimes an ecosystem may be so badly degraded that it is unable to recover naturally. In such cases, it may be possible to actively restore the ecosystem. This can be done in a number of ways, depending on the ecosystem. Usually, active restoration involves the direct transplantation of organisms back into the damaged ecosystem (e.g., planting of mangroves or transplantation of coral from a less degraded site to a more degraded site). Active restoration needs to be carried out carefully, with a full understanding of the local ecosystem, and should only be attempted as a last resort measure if natural restoration is seen to be unfeasible.

It is important to note that active restoration should only be carried out in order to help the recovery of species/ vegetation that have disappeared from an area as a result of human abuse. Restoration techniques should not be used to attempt creating a "new" ecosystem in a place where it was previously not found (e.g., planting mangroves along sandy beaches).

An overview of how active restoration can be carried out for mangrove and coral reef ecosystems is given below. It should be noted that restoration requires careful planning and should be carried out only through programmes developed and led by experts in the field.

(i) Mangrove restoration
The restoration of mangrove ecosystems is usually carried out through replanting vegetation that has been lost. If natural recruitment is not sufficient, propagules or seedlings can be harvested from healthier areas. While propagules may be planted immediately in the area to be restored, they are commonly grown to larger sizes under controlled conditions in a nursery, which increases the likelihood of survival.

In order to be carried out properly, and to maximise the conservation value of restoration activities, mangrove restoration needs to address a number of issues. For example, the mangrove area that is being restored should only use species that would have been found naturally in the same area, and the natural distribution of different species in mangrove should be replicated. Planting may only be possible at certain times of the year and may be affected by seasonal changes, such as the monsoon.

Figure 5.4. A mangrove nursery in Pakistan
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Other factors, such as the type of soil, landscape features and tidal patterns, must be understood before planting can be carried out. Depending on the hydrology of the area, the ground may need to be prepared (e.g., through digging water channels) to ensure that there is enough water exchange to support a healthy ecosystem. Because there are many factors that need to be considered, it is important that restoration is carried out under the supervision and guidance of experts.

The replanting of mangroves in areas affected by the Asian tsunami of 2004 is a good example of how active restoration techniques can be used to repair damaged ecosystems. In many parts of India, Indonesia, Sri Lanka and Thailand, mangroves were damaged by the tsunami; restoration has, in many of those areas, significantly helped the natural recovery process and prevented the permanent alteration of ecosystems.

(ii) Coral reef restoration

Many rehabilitation techniques have been attempted in efforts to repair damaged coral reefs, including: constructing artificial reefs using structures made of cement; “electric” reefs constructed of metal and including an electric power source to facilitate precipitation of calcium carbonate and other minerals; consolidation of reef areas with moving rubble, using cement or other binding materials; and transplantation, using living corals.

While coral reef rehabilitation may aid recovery of damaged reefs by enhancing natural processes, there is scant evidence of benefits being derived beyond simply good management, which, in any case, is essential for restoration to be successful. Also, as techniques tend to be difficult and comparatively expensive, interventions are likely to work only over limited areas. Thus, coral restoration needs to be approached with caution, and only by experts, based on a careful assessment of options available, and first and foremost by addressing the factors that are causing degradation and preventing recovery.

5.4. Suggested activities

(a) Meeting the protected area managers

Purpose: An informative talk given by someone responsible for ecosystem or species conservation will allow children to understand what type of conservation activities are being carried out in their local area.

Activity: The teachers can invite local protected area (e.g., MCPA or MPA) managers, forest department officers, local environment wardens, dive instructors involved in ecosystem protection or any other person who is involved in the conservation of local coastal and marine ecosystems, for a discussion with the children. The guest speaker should give a 30- to 60-minute talk describing: the area that they are involved in protecting; which animals and plants or ecosystems are being protected; why this area is important; and outlining the type of management activities that are being used. The following questions can be provided as guidance for the manager:

- Where do you work and why is it a protected area? Describe the ecosystem area and highlight important animals, plants and other features. Describe the issues faced by the area and reasons why protection is needed;
- What kind of protective measures have been put in place in the area? Outline what kind of protective status is given to the area and the species associated with it (e.g., protection of nesting sites, restriction of fishing and prohibition of extracting resources);
- What kind of management is the site under? For example, whether the site is managed by the state/communities/privately. Give an overview of the management structure and regime (e.g., boundaries, zones and patrolling);
- What types of activities take place in the protected area? Describe interesting management actions (e.g., turtle tagging, community-based nest monitoring, restoration activities and tourism).

The students can also discuss the permitted and prohibited activities in the protected area. Speakers should be encouraged to use visual aids in their talks, such as an illustrative slide show.

(b) Stakeholder role simulation

Purpose: Each student will be asked to assume the role of different stakeholders and think about management issues from different perspectives. This activity will help children to think about how various groups have different interests and how they interact with each other.

Activity: If the students have had the opportunity to explore coastal and marine resource use during a field excursion, they should now have an idea about the different direct and indirect users of local resources. Divide the class into groups of five students. Each student should be given a role as a coastal zone user. The different resource users that are chosen for the role play will depend on the common activities carried out in the local area.

Examples of some of the roles that groups might consider include: fisheries-related activities (e.g., bait digger, fisher, spear fisher, dynamite fisher, boat builder, shrimp farmer or fish trader); tourism- and development-related (e.g., hotel developer, tourism guide, rubbish dump developer, harbour developer, housing developer or dive master); other direct resource harvesters (e.g., mangrove cutter, shell collector or seaweed farmer); and other stakeholders (e.g., local conservation or protected area representative, school teacher, religious leader, school nature club representative, business-person or police-person).

Each group should imagine that a stretch of coastline in their vicinity is being sold for some development purpose (e.g., for shrimp aquaculture or tourism); each user, including the proposed developer, will be given an opportunity to explain why their activity should be allowed. Each student should be given 15 minutes to prepare his/her arguments. The role play should simulate a community meeting that has been convened in order to discuss what activities are being carried out in the coastal area and whether the land should be sold. Each group should act out their roles for 5 to 10 minutes, with the rest of the class acting as judges, with a final agreement on a course of action. Encourage the judges to think about how different uses can be reconciled and how a compromise can be reached between the different users.

(c) Visit to a mangrove or coral reef active restoration site

Purpose: If there are active restoration activities being carried out on mangrove or coral reef ecosystems near the students' town or village, a field trip could be organised to allow students to see these activities at first-hand.

Activity: Approach the authority responsible for restoration activities and arrange an excursion plan and time. The students can be taken to areas where active restoration of an ecosystem is being conducted and shown how restoration is carried out. If the area being visited is a coral reef, a guided snorkelling trip or a glass-bottomed boat trip can allow students to view the restoration sites. In the case of mangrove restoration, the group should visit a restoration programme and, ideally, the students should be invited to take part. Students could, for example, be involved in planting (under the supervision of a trained professional) and allowed to revisit the site over time to see the progress of planted propagules.

Figure 5.5. School children involved in mangrove plantation activities in the Lakshadweep Islands, India

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Appendices

I. Where to find more information

References

Odum, H.T., 1988. Energy, environment and public policy: A guide to the analysis of systems. United Nations Environmental Programme Regional Seas Reports and Studies No 95, Geneva.

Rao, S., 1996. *Treasured Islands: An Environmental Handbook for Teachers in the Andaman and Nicobar Islands*. Kalpavriksh Publications, Pune, India.

Zicus, S., 2003. Investigating ecosystems: An action research approach to local environmental investigations. Bright Minds Project, University of Queensland, Australia.

Other useful sources of information

Ambassadors of the Environment Educational programmes
www.aote.org
Coral reef slide show from Ocean Futures Society's Hawaii programme – www.aote.org/menu/ss/index.htm

Australian Institute of Marine Science
www.aims.gov.au/index.html
Project Net: School project resources for marine science subjects for teachers and students – www.aims.gov.au/pages/research/project-net/apnet.html

Caribbean Conservation Corporation
www.cccturtle.org/ccctmp.htm
CCC and its Sea Turtle Survival League are dedicated to protecting sea turtles through research, education, advocacy and protection of their habitats. They have a listing of a variety of education materials available – www.cccturtle.org/sat1.htm

Co-operative Research Centre for the Great Barrier Reef World Heritage Area (CRC)
www.reef.crc.org.au
CRC is a knowledge-based partnership of coral reef managers, researchers and industry. There is a Seagrass Adventures section on the website that was designed by children from Bentley Park College and scientists from CRC – www.reef.crc.org.au/seagrass/index.html

Coral Cay Conservation
www.coralcay.org/index.html
Provides resources to help sustain livelihoods and alleviate poverty through the protection, restoration and management of coral reefs and tropical forests

Coral Reef Alliance
Various educational materials and teachers' resources available under Professor Polyp where you will find a new lesson about coral and coral reef creatures every month –
www.coralreefalliance.org/resources/

Coral Reefs – Cities under the Sea
This comprehensive book on coral reefs and its companion book are available from www.Amazon.com or directly from Richard Murphy (rmurphy000@aol.com). Another useful resource is the "Exploring the Ocean and Coral Reef Ecosystem" workbook (included in the Sustainable Reefs package) from Gina Lemieux at GLemieux@golder.com or rmurphy000@aol.com.

Ecological footprint

Visit the website at www.earthday.net/footprint/index.asp to figure out your own ecological footprint, either individually or as a group. Discuss ways in which we can alter our lifestyles to help decrease our ecological footprint.

Global Coral Reef Alliance

www.globalcoral.org/

International Coral Reef Action Network (ICRAN)

www.coralreeffund.org/

ICRAN is a collaborative effort working to halt and reverse the decline in health of the world's coral reefs.

International Coral Reef Initiative

www.icriforum.org/

The International Coral Reef Initiative (ICRI) is a partnership among nations and organisations seeking to implement Chapter 17 of Agenda 21 and other international Conventions and agreements for the benefit of coral reefs and related ecosystems – www.icriforum.org/secretariat/pdf/agenda21cap17.pdf

International Year of the Reef

www.iyor.org

Provides extensive information about coral reefs and has a section on educational resources that link you to several other sites that work on coral reefs and related ecosystems.

Mangrove Action Project

www.mangroveactionproject.org

A non-profit organisation dedicated to the protection of the world's mangrove ecosystems.

The Nature Conservancy

http://nature.org/

Reef rescue programme – http://nature.org/joinanddonate/rescuereef/. New hope for coral reefs information page – http://nature.org/magazine/fall2002/coralreefs/

National Centre for Caribbean Coral Reef Research

www.ncoremiami.org/index.htm

Located on the campus of the Rosenstiel School of Marine and Atmospheric Science at the University of Miami, the Centre's focus is on the analysis and prediction of coral reef resilience in order to improve the scientific basis of coral reef management.

Nemo's websites

Coral Reefs – Cities under the Sea – www.oceanfutures.org/Nemo/index.html. See also Mr. Ray's Classroom reef panorama with hot spots that provide information about "critters" – http://disney.go.com/disneyvideos/animatedfilms/findingnemo/index2.html.

NOAA: National Oceanic and Atmospheric Administration

- The Coral Reef Information System Web site (CoRIS) – www.coris.noaa.gov/
- Discovery Classroom – Coral Reef Conservation – www.nos.noaa.gov/education/classroom/01_coralreef.html
- Coral Reef Resource Roundup – education and outreach materials on CD
- United States Coral Reef Task Force. Contact: Alissa Barron, Outreach and Education Co-ordinator, NOAA Coral Reef Conservation Programme at Alissa.Barron@noaa.gov
- Local Fisheries Knowledge (LFK) Project, designed to give students an opportunity to learn about their cultural connections with the sea, understand changing fisheries resources and connect with their elders – www.st.nmfs.gov/lfkproject/.

The Ocean Conservancy
www.oceanconservancy.org

Ocean Futures Society
A variety of resources and web experiences available on Jean-Michel Cousteau's many programmes and adventures – www.oceanfutures.org
Jean-Michel Cousteau Ocean Adventures – television series in partnership with PBS and KQED. See also lesson plans, games, activities and background materials at the website www.pbs.org/oceanadventures

Reef Base
Online information system on coral reefs – www.reefbase.org

Reef Check
Dedicated to global coral education, monitoring, and management. The home page at www.reefcheck.org/ provides a link to Reef Check's Five-Year Report – "Trends and solutions: The coral reef crisis".

Reef issues
www.globalcoral.org/reef_issues.htm

Reef Relief
Reef Relief's Education Centre provides educational materials including teacher's guide, scripted slide presentation, posters and more – www.reefrelief.org/main.html

Save Our Seas
Ocean Pulse coral reef project at schools and on the Internet educates the community about coral reef ecology – www.saveourseas.org/
See also www.saveourseas.org/overview2003.htm

Sea and Sky
www.seasky.org/reeflife/sea2.html
Educational resources, images, and games for ocean exploration.

The University of Queensland
www.reef.edu.au/

The University of the Virgin Islands
www.uvi.edu/pub-relations/uvi/home.html
Coral Reef Ecology home page – www.uvi.edu/coral.reefer/index.html

The World Fish Centre
www.worldfishcenter.org/
The Centre is committed to contributing to food security and poverty eradication in developing countries.

World Resource Institute
Informative power point presentation "Reefs at Risk" – www.wri.org
See also www.wri.org/powerpoints/reefswww/sld001.htm

WWF-World Wide Fund for Nature
www.wwf.org
Resource Management Education Programme provides educational training for teachers; publication/audio-visual catalog available.

II. Glossary

Term	Explanation
A	
Abiotic	Components of the physical environment that were never alive; e.g., water, rocks, light and temperature.
Accuracy	The closeness of a measurement to the true value.
Acid	Compounds that break apart in water to form hydrogen ions (H+).
Acidic	Having a high hydrogen ion concentration (low pH).
Algae	Simple plant-like organisms that contain chlorophyll but lack roots, stems or leaves.
Anaerobic	Organisms that do not require oxygen for respiration; environmental conditions where oxygen is lacking.
Aquatic	Referring to a water environment.
Atmosphere	The mixture of gases that surrounds the Earth, consisting mostly of nitrogen, oxygen, carbon dioxide and water vapour.
Autotroph	An organism capable of making its own food nutrients or simple organic substances.
B	
Basin	The low point in a catchment where surface water collects; also called base level.
Bias	An intentional or unintentional distortion of observations, data or calculations in a non-random manner.
Biogeochemical cycle	The process by which an element cycles through the biosphere.
Biome	A large-scale global ecosystem that is defined by the structure of the vegetation as well as the form and function of the animals that live in that ecosystem.
Biotic	Material and organisms that are alive or were once living.
Bloom	A sudden massive increase in the number of producers such as algae or aquatic plants per unit of water; generally consisting of one or a few different species.
C	
Carbon cycle	The bio-geochemical cycle in which carbon moves through the biosphere.
Carnivore	An animal that eats other animals.
Catchment area	An area that collects and drains precipitation.
Climate	The average weather (temperature and precipitation) in an area over an extended period of time (usually 30 years).
Community	All of the different species of organisms that live and interact within a given geographic area.
Condensation	The process by which a vapour becomes a liquid.
Consumer	An organism that gets its energy by feeding on other organisms and their remains. Includes herbivores, carnivores, scavengers and decomposers.
Cover	The amount of surface area occupied by ecosystem component being measured, usually expressed as a percentage of the total area.
D	
Decomposer	An organism that feeds on dead organisms from all levels of the food chain, causing mechanical and chemical breakdown of the organisms and returning nutrients to the environment.

Degree	A measurement of angle (1/360th of the circle); further divided into minutes and seconds.
E	
Ecological pyramid (see also trophic diagram)	Diagram showing the relative amount of available energy at each trophic level in an ecosystem.
Ecosystem	A group of organisms and the environment in which they interact. All components of an ecosystem are tied together in a complex relationship of energy and nutrient flow.
Equator	An imaginary line of reference around the Earth that is midway between the poles or rotation. It is designated as O (Zero) latitude.
Erosion	The removal of weathered rock material or soil from a specific location by wind, water or ice.
Estuary	A semi-enclosed coastal body of water with one or more rivers or streams flowing into it, and with a free connection to the open sea.
Eutrophication	The enrichment of water by nutrients such as phosphorus and nitrogen, leading to enhanced growth of aquatic algae and plants; this lowers light penetration of the water, leading to higher rates of death and decomposition and decreased levels of dissolved oxygen in the water.
Evaporation	Process by which liquid water is converted to water vapour.
Evapotranspiration	Water vapour returned to the atmosphere through direct evaporation and transpiration by plants.
Exoskeleton	An external skeleton that protects and supports an animal's body.
F	
Food chain	The transfer of energy from produce through a linear sequence of consumers.
Food web	A complex network of interlocking food chains.
G	
Gross domestic product (GDP)	A measure of national income and output for a given country's economy, defined as the total market value of all final goods and services produced within the country in a given period of time (usually a calendar year).
Groundwater	All water present below the surface of the Earth.
H	
Habitat	The living environment of an organism that provides the needed food, water, shelter and space.
Hemisphere	Half of a globe; may be either eastern and western, or northern and southern hemisphere.
Herbivore	A plant eater.
Heterotroph	An organism that cannot make its own food, and which eats other organisms or complex organic substances that are produced by other organisms.
Humus	The partially decomposed remains of dead plant and animal tissues.
Hydrologic cycle	A simplified model of the movement of water through Earth's systems.
Hydrology	The science or study of water. This includes understanding the Earth's water-based systems, such as tides and river flows.
Hydrosphere	All of the Earth's water, including oceans, lakes, streams, underground water snow and ice.

I	
Insect	An arthropod animal of the class Insecta, which has three pairs of legs and a body segmented into head, thorax and abdomen.
Invertebrate	An animal that does not have a backbone or an internal skeleton made of bone or cartilage.
K	
Key	(Map.) An explanation of the meaning of symbols used on a map; also referred to as a map legend.
L	
Latitude	Distance on the Earth's surface measured in degrees, minutes and seconds, north and south of the equator.
Lithosphere	The solid, inorganic portion of the Earth that is composed of rocks and minerals.
Longitude	Distance on the Earth's surface measured in degrees, minutes and seconds, east and west from the prime meridian.
M	
Magnetic field	The lines of magnetic force generated by the Earth's core that surround the planet.
Matter	Anything that occupies space and has mass.
Micro-organism	An organism that is too small to be seen with the naked eye.
N	
Niche	The role or function of an organism in an ecosystem; may be considered in terms of energy flow (strophic level), reproductive strategies or habitat needs.
Nitrate	An inorganic compound of nitrogen (NO) is an important nutrient for plants and animals.
Nitrogen	The most abundant gas on Earth, making up approximately 78per cent of the Earth's atmosphere.
O	
Omnivore	An animal that consumes both plants and animals.
Organic	Matter containing carbon-based compounds.
Organism	A life-form such as a plant, animal, protist, fungus or bacteria.
P	
Parameter	A measurable or quantifiable characteristic.
Perimeter	The outer boundary of an abject or area.
Phosphate	A form of phosphorus, an essential nutrient for the growth of living organisms.
Photosynthesis	A metabolic pathway that converts light into chemical energy.
Population	The number of individuals of a single species in a defined area.
Population density	The average number of individuals of the organism or organisms under study in a given area, expressed as a number per unit area.
Precipitation	Water that falls from the atmosphere to the surface; may be in the form of rain, snow, hail or sleet.
Precision	A measurement of the degree of consistency in the multiple analyses of a sample.
Producer	Organisms such as plants that use inorganic substances to synthesise organic compounds.

Q	
Quadrat	A simple area, usually a square, chosen as a basis for studying selected features or organisms.
R	
Random sampling	An unbiased selection process in which all of the features or organisms to be studied have an equal chance of being selected.
Range	The amount of space needed by an animal in order to meet its survival needs.
Replicate	To repeat the same test using the same methodology and equipment.
Respiration	A complex series of chemical reactions involving oxygen that make energy available for use by living organisms, and result in the production and release of water and carbon dioxide.
S	
Salinity	The concentration of dissolved solids in water, including soil water.
Sand	In soil science, mineral particles that range from 2-0.05 mm in diameter.
Scale	(Maps.) The ratio of a unit of distance on the Earth's surface to the distance it represents on a map or globe.
Scavenger	Animal that eats the remains of dead animals or plants.
Scuba-diving	Underwater diving using self-contained underwater breathing apparatus (scuba).
Secondary consumer	An animal that feeds on herbivores or primary consumers.
Selective sampling	Purposeful selection of variables to be measured.
Silt	In soil science, mineral particles that range from 0.05-0.002 mm in diameter.
Slope	Degree of inclination of the ground surface from horizontal.
Soil	Unconsolidated mineral and organic material at the Earth's surface formed by physical and chemical weathering of underlying rocks and altered by biological processes.
Subsoil	The soil below the top soil containing no humus.
Subtropics	The zones of the Earth immediately north and south of the tropical zone.
Symbiosis	A long-term interaction between two species that can often have mutual benefit for both species.
T	
Tertiary consumer	An animal that feeds on secondary consumers.
Thermal pollution	The discharge of heated water into an aquatic environment.
Tolerance level	A measurement of the ability of an organism to withstand changing or adverse environmental conditions over an extended time.
Topography	The surface features of the land.
Transect	A sampling area along a path or straight line.
Trophic diagram (see also ecological pyramid)	Diagram showing the relative amount of available energy at each trophic level in an ecosystem.
Trophic level	A given organism's position on the food chain.
Turbidity	A measurement of the cloudiness of water; based largely on suspended solids in the water.

V	
Variable	Any changeable factor that can influence the results of an experiment or observable phenomenon.
W	
Watershed	The ridges, hills and mountains that divide two catchments; also called a drainage divide.
Water table	The upper surface of groundwater; the pore spaces in the soil below this level are filled with water.

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