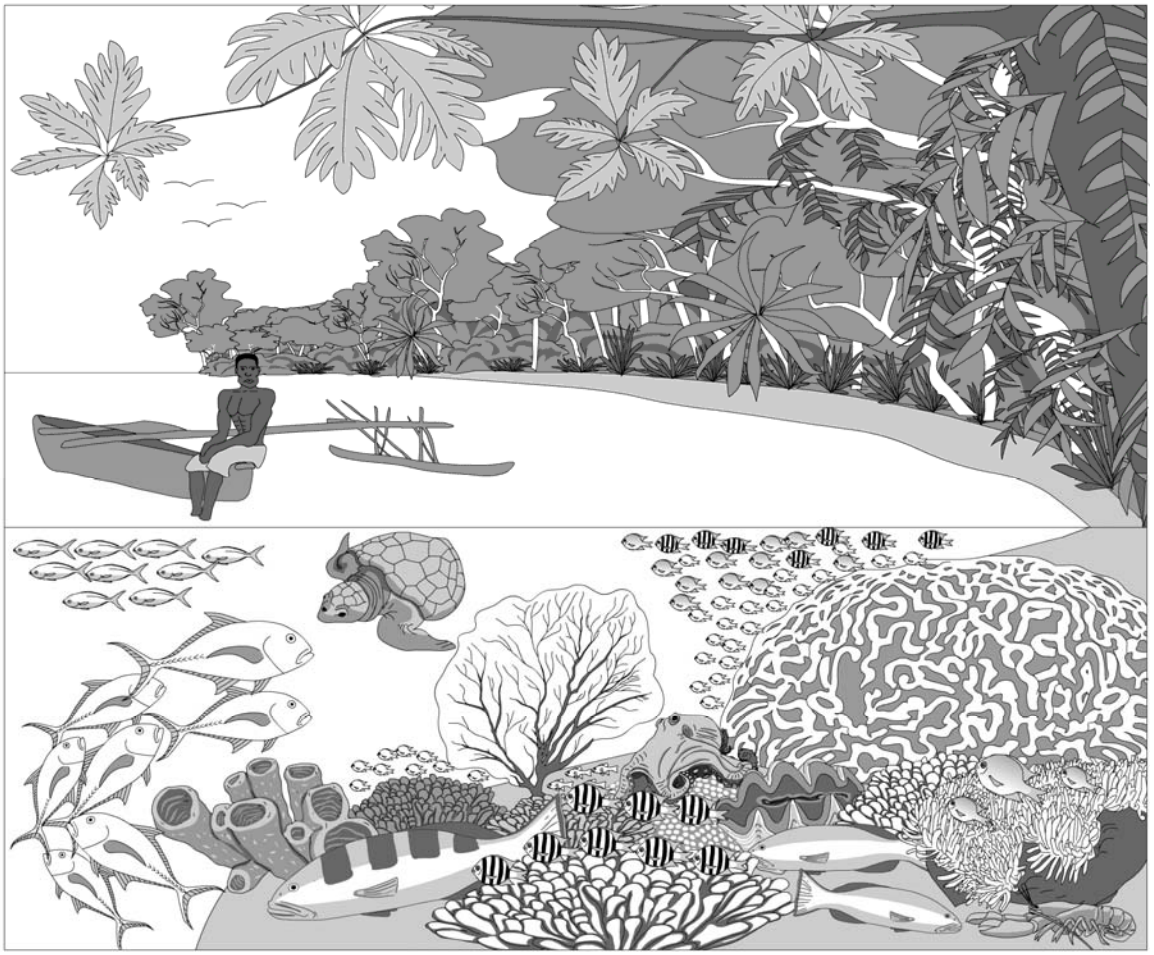
MARINE
ENVIRONMENTAL EDUCATION PROGRAM

CORAL REEFS



Biology, Ecology, Threats & Impact Prevention

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RESEARCH & CONSERVATION CENTRE

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About this document

This document was designed not only as a course manual for the Marine Environment Education Program conducted by the Mahonia Na Dari Research and Conservation Centre, Kimbe Bay, West New Britain Province, Papua New Guinea, but also as an educational awareness document in its own right. Whilst the educational value of this document should not be limited by global geography, the document's content is especially relevant to all Indo-Pacific and Southeast Asian nations whose seas are home to coral reefs.

The Mahonia Na Dari Research and Conservation Centre adheres to the principal of ***conservation through education***. Thus their Marine Environment Education Program is committed to educating both children and adults about tropical marine environments, about human activities that affect these environments, and about ways in which the harmful effects of these human activities can be reduced and eliminated. It is through such awareness programs that human attitudes towards the environment can evolve so that people will embrace the role of guardians over their natural resources. It is only through such guardianship that man will be able to prosper from these natural resources over countless generations.

Acknowledgements

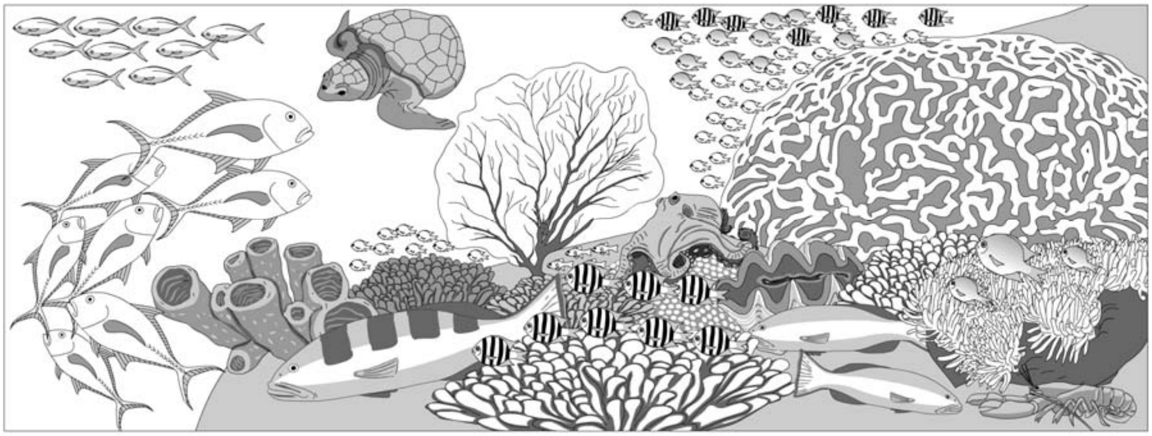
A great deal of hard work went into this document. Thanks to all those involved directly with the writing (Philip Lahui, Lesley Bennett, Stanley Waypot, and John Claydon), editing (John Claydon, Natalie Reed) and also those whose work in the past with the Marine Environment Education Program at Mahonia Na Dari set the foundations for such a document to evolve in the first place (Margit Luscombe, Sayam Papua, Tim Keneally, and Wayne Kiefer)

Part 1

Coral reef geography, biology & ecology

PART 1: CORAL REEF GEOGRAPHY, BIOLOGY & ECOLOGY

Introduction



Coral reefs are one of the Earth's most complex and diverse ecosystems. Coral reefs have evolved over long periods of geological time in response to certain natural phenomena including tectonic movements, changes in climate and associated changes in sea level. The oldest known coral reef appeared more than 450 million years ago and by 150 million years before present, corals had diversified and spread globally throughout tropical shorelines.

As one of the planet's prime ecosystems, coral reefs are centres of biodiversity and primary productivity. They convert sunlight into food and provide habitats to a wide range of marine organisms. Many island and mainland people depend on coral reefs for food and building materials. They are popular locations for tourism and recreation, and coral reefs are potentially a major source of new medicines. Incredibly, all of this, as well as their well-known beauty, hinges on the symbiotic relationship between two simple organisms: a tiny soft bodied animal (coral ***polyp***) that contains an even smaller single celled plant (***zooxanthellae*** **–** algae). The coral polyps live in colonies, and together they secrete a calcium carbonate (limestone) skeleton as they grow. This calcium carbonate skeleton is responsible for the formation of coral reefs.

Corals come in all forms: shaped like branching trees, boulder-like, tiny pipes or saucers. Reefs take on their unique structure as this variety of corals grow, then die leaving behind a limestone skeleton on which new corals settle and grow, then die themselves leaving more limestone skeletons upon which other new corals can become established and grow. The complicated matrix of holes, boulders, caves and rubble that results houses an enormous diversity of animals.

Coral reef geography

Coral reefs are distributed extensively within the shallow regions of the Earth's tropical oceans. They occur almost exclusively between 30° North and 30° South latitudes, and are concentrated in four large tracts: the Red Sea and Western Indian Ocean, the Indian and Western Pacific Ocean (the Indo-Pacific), the South Pacific Ocean, and the Caribbean Sea and Western Atlantic Ocean. Of these four tracts, the Indo-Pacific coral region has the world's greatest diversity of marine organisms.

The Global Distribution of Coral Reefs

Although coral reefs are spread globally throughout the tropics, collectively, they cover less than 0.25% of the ocean's area – probably less than 600,000 square kilometres. Within this small global area, coral reefs harbour an incredible biological diversity, including over 800 species of coral and more than 3000 species of fish. The diversity of coral reefs equals that of any terrestrial ecosystem including equatorial rainforests.

Because of their dependence on sunlight for energy, and tropical waters for warmth (from about 20°C to 30°C), coral reefs flourish in the shallow parts of equatorial seas along low latitude continental and isolated coasts. Coral reefs are more extensive on the western sides of ocean basins where warm water has a greater latitudinal distribution than on the eastern sides. This is because the warm low latitude ocean surface currents that flow westward change direction suddenly heading north and south off the eastern coasts of Asia, Australia, North and South America and Africa. Conversely, in the eastern reaches of ocean basins, coral reefs have a much more limited north-south distribution, because cold water currents off the western coasts off North America, South America and Africa restrict their range and diversity. For example, although the Galapagos Islands and the Indonesian Islands of Sulawesi and Halmahera are all located astride the equator, the Galapagos has very few species of coral, while the reefs around Sulawesi and Halmahera are among the world's most diverse. The cold-water current from Peru limit coral growth in the equatorial eastern Pacific (the Galapagos Islands), while coral growth in the equatorial western Pacific (Sulawesi and Halmahera) is enhanced by warm water brought by the westward flowing South Equatorial Current.

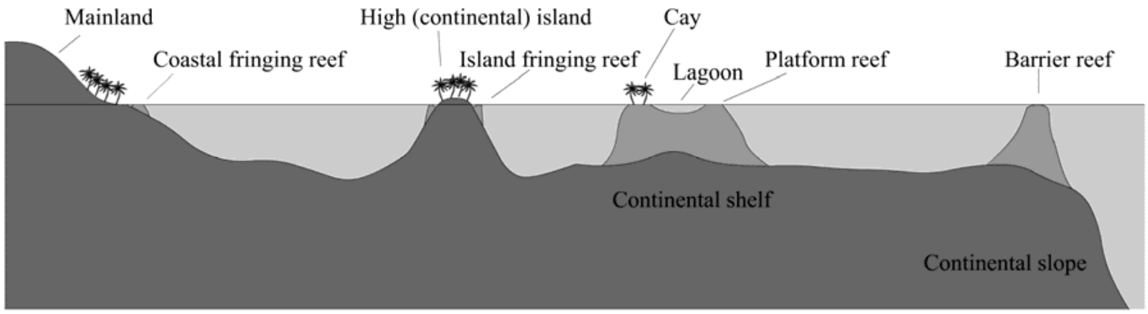
The geographic distribution of coral reefs is also limited to relatively clear waters with normal oceanic salinities. Coral reefs do not develop off the mouths or deltas of large tropical rivers or along high rainfall coastal plains because sediments in the water column reduce the transmission of sunlight through the seawater inhibiting photosynthesis by the zooxanthellae. Polyp growth is suppressed by sediment clotting and by freshwater that diffuses through the polyp's cellular membrane creating a chemical imbalance that may cause polyps to die. Very little coral grows along the Northeast coast of South America because of the vast plumes of sediments discharged by the Amazon River. This forms a natural barrier for coral development and prevents exchange of genetic stock with the Caribbean.

The geographic location of coral reefs plays a large role in determining what sort of pressures these reefs are put under from human activities. Differences in the economies, politics, cultures, population densities and legal systems of the countries where coral reefs occur all contribute to the health of these reefs. For example, the world's centre of coral and marine diversity in southeast Asia overlaps with areas of high population density, large coastal cities, high levels of pollution from agricultural and urban sources, and destructive reef fishing using explosives or cyanide. It is for these reasons that this region also has the world's greatest concentration of threatened reefs. However, under different socio-political conditions, the nearby Great Barrier Reef is the world's most protected large coral reef complex. Similarly, with generally low human populations and few large cities or mainland sources of pollution, coral reefs in the Red Sea and South Pacific are less threatened.

Coral reef formations

The ability of corals to construct and maintain a stony habitat creates abundant shelter and attachment for other organisms, which is the keystone of the reef community's richness and stability. This is because shelter and attachment is scarce and limiting resource in the sea for most of the sea floor is a featureless plain of sediments. The ability of reef corals to secrete the immense volumes of limestone necessary to create a reef is due to the intimate physiological relationship of reef building corals and their zooxanthellae. Unlike rocky outcrops, coral reefs can follow changing sea levels, grow, and maintain themselves.

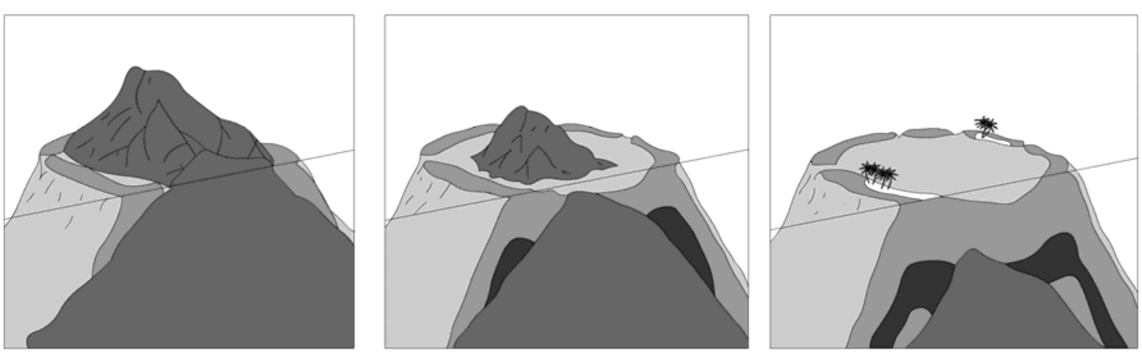
Different structural types of coral reef



- ***Fringing reefs*** are the most common type of coral reefs. They develop adjacent to the shore along continents and islands.
- ***Platform reefs*** are large areas of reefs not joined to mainland that reach the surface from the shallow continental shelf.
- ***Patch reefs*** are small, isolated, patches of coral that can be found near fringing or platform reefs and in lagoons.
- ***Barrier reefs*** are continuous areas of reef that often develop far away from the coastline, such as on the edge of the continental shelf.
- ***Atolls*** are circular reefs that arise from deep-sea platforms such as submerged volcanic seamounts.

A fringing reef around a volcanic island can grow upward at a rate matching the gradual subsidence of the volcanic material back into the plastic crust of the Earth. The result is a reef community maintaining itself for thousands or millions of years and in the process creating a coral atoll.

Coral Atoll Formation

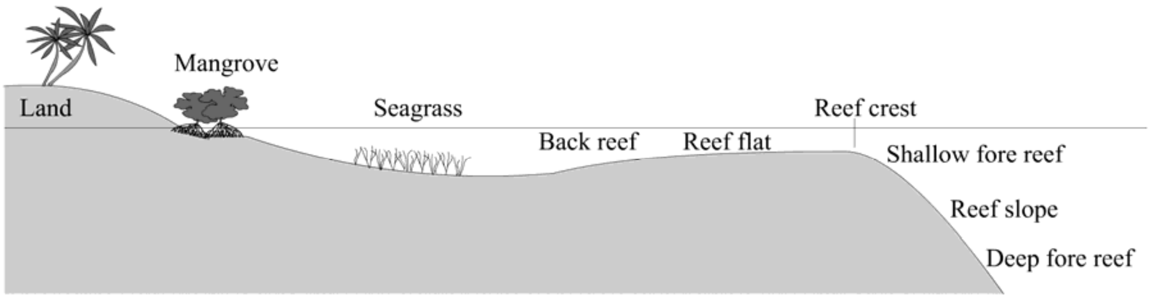


As the mountain (or volcano) with fringing reefs subsides slowly enough to allow the reefs to continue growing, then a chain of reefs encircling a lagoon will eventually be formed. This results in the formation of a coral atoll.

The physical environment and reef community structure

Different parts of a coral reef are subject to different environmental conditions. These different areas are called ***zones***, and are characterised by physical factors such as depth, exposure to waves and turbidity. For example, the ocean side of the reef is exposed to waves and the water is usually clear. Inside the lagoon, water is calmer but cloudy. The different zones form different habitats, which house distinctive assemblages of organisms

A typical reef consists of many zones:



- **The deep fore reef** is an area where organisms that depend on light for calcification or photosynthesis have become flattened to increase their surface area so they get as much light as possible. As shown by some stony corals that form pillars in shallow water become plate-like as depth increases.

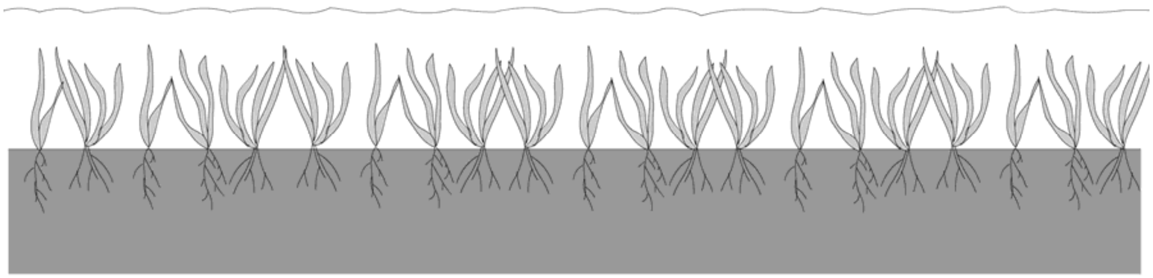
- **Shallow fore reefs** are exposed to at least moderate winds and waves. Various coralline red algae occur in what is usually the most turbulent water area and grow as a thin crust or in small fan like forms. Animals found here are well adapted to hanging on during extreme wave conditions. Some, such as the spiny lobster, may hide in the reef during the day and then move on to the reef flat at night to feed. Others, such as the sea urchin, dig deep grooves into the rock where they are protected from wave action.

- **The reef flat** is often a rocky pavement, flat, with only small grooves and crevices or cracks in its surface. A number of organisms occur only on the reef flats. Some remain on the reef flat even at low tides when it is exposed, quite often hiding in crevices. Other animals migrate onto the reef flat only when the tide is high enough to feed.

- **Behind the reef flat** there is usually a shallow coral area of sandy slope as the depth increases. These sediment bottoms house many invertebrates, which remain hidden in the sand during the day. Mitre shells and cone snails, emerge from the sand to search for food at night.

Associated habitats

Seagrass

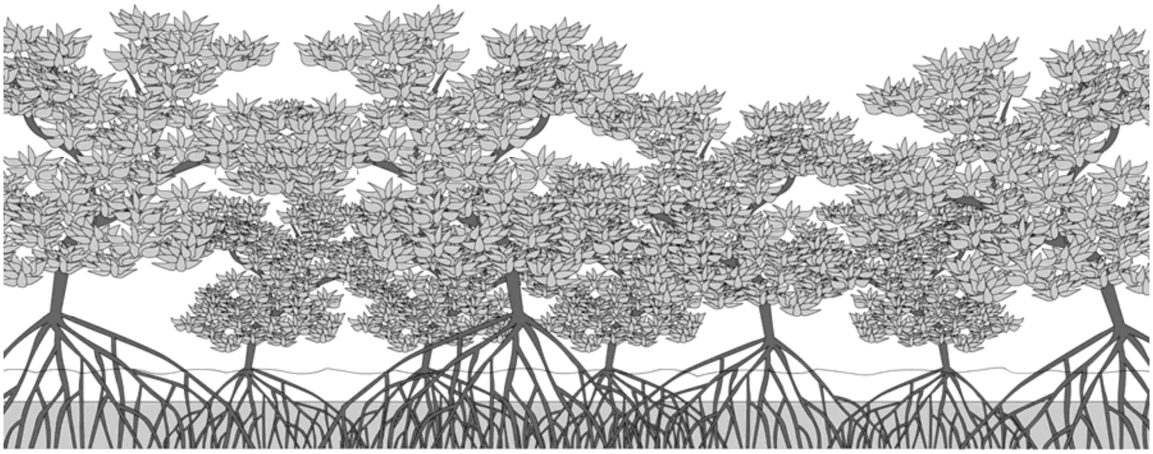


A common back reef habitat is the seagrass bed. Seagrass beds are the grasslands of the sea. Seagrasses are flowering plants that usually grow in soft-sediment areas. They have erect elongate leaves and buried root-like structures (rhizomes).

- Seagrass beds are a habitat for many animals. There is shelter and cover provided by the numerous dense blades of the plants and high production of plant material for food. Many algae also occur within seagrass beds while the blades of the seagrass provide a surface where other organisms, both plants and animals, can grow. Some of these animals include, ascidians, bryozoans, sponges, and plants (diatoms and other algae). These are a source of food for many invertebrates, such as snails, clams, sea cucumbers, and sea urchins.

- Seagrass beds are locations in which burrowing organisms can live because the dense mat of rhizomes holds down the sediment firmly. Seagrass beds trap and stabilise sediments, thereby protecting other coastal habitats from excessive sediment loads.

Mangrove

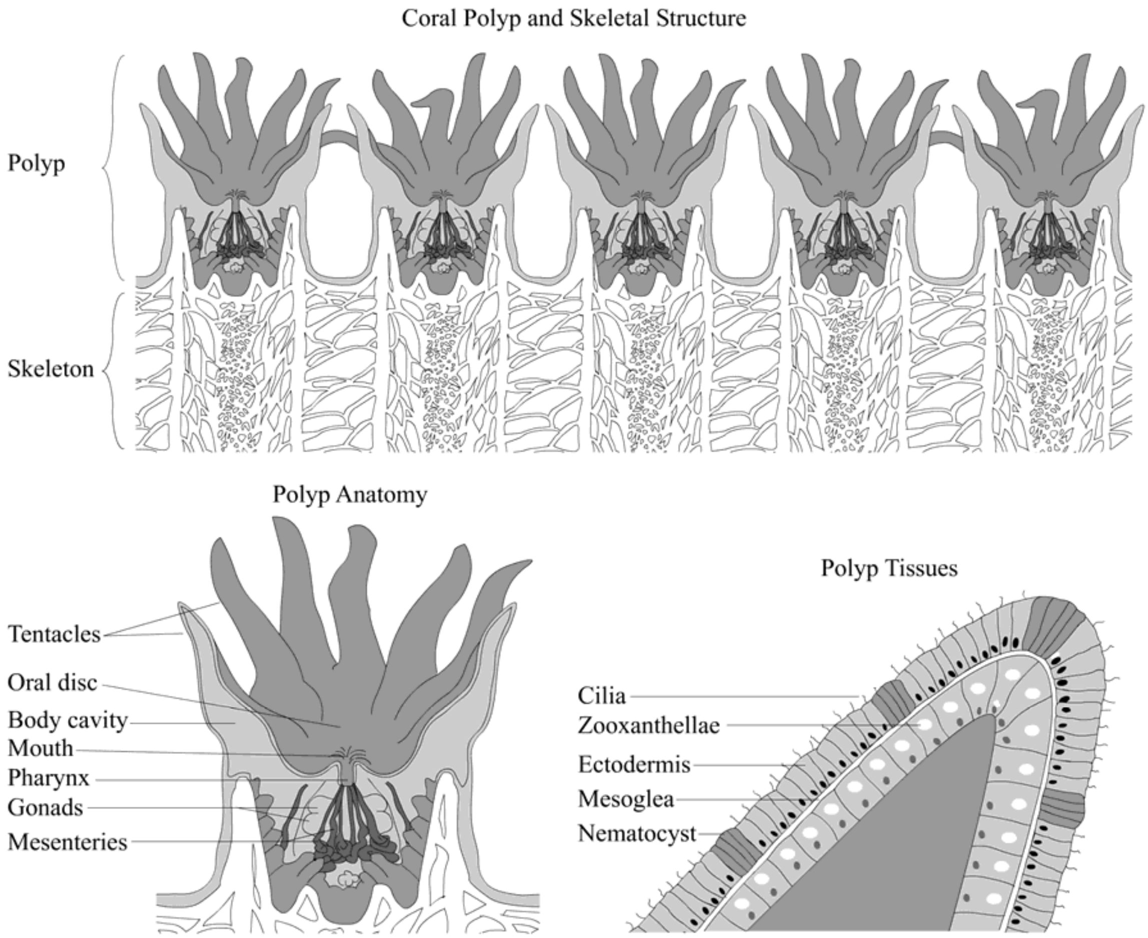


Generally defined as woody shrubs and trees that grow in salt or slightly salty water below the high tide level, mangroves can form broad stands or narrow fringes along shores.

- Water flows in and out of the mangrove with the tide, producing currents that carry nutrients that encourages the growth of crustaceans such as shrimps and crabs on the mangrove roots. Water in mangrove areas is usually fairly cloudy, but can be clear on a high tide. The red mangrove is perhaps the most easily identified of the mangroves with extensive systems of prop and aerial roots. These submerged roots provide a substratum for many other encrusting organisms.

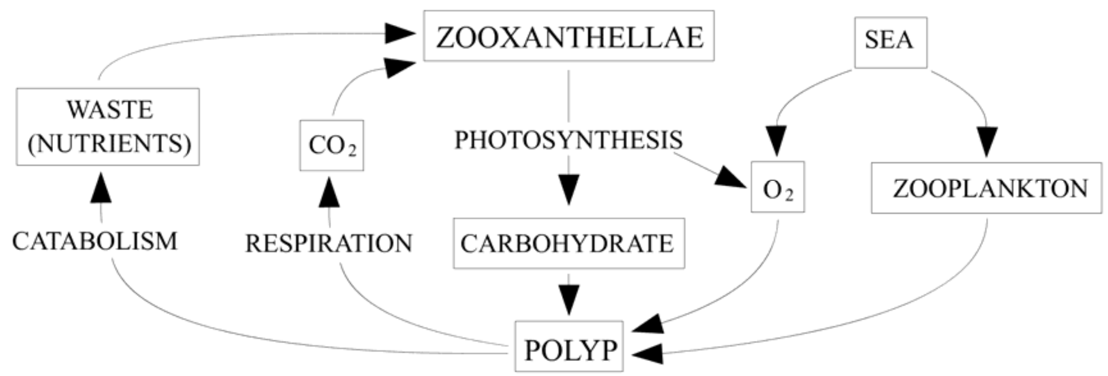
- The network of roots typical of mangrove areas serve to trap sediment run off from land and creeks. The trapping of sediment allows the mangrove forests to grow seawards. Mangroves are important in the protection of coastal habitats, limiting the sediment input onto fragile habitats such as coral reefs.

Corals, polyps and zooxanthellae



Corals may look like colourful bits of rock, but they are actually colonies of tiny animals called polyps. The coral polyp has a simple structure similar to that of sea anemones. The coral polyp is a soft cylinder of tissue closed at the bottom, with a mouth surrounded by tentacles at the top. Inside is an open stomach cavity, partitioned by radiating strips of tissue. The coral polyp is related to the jellyfish and, like these, its tentacles contain tiny stinging cells. Unlike a jellyfish it has an external skeleton underneath. Corals are formed by colonies of polyps connected to each other by extensions of their tissues, even their stomach cavities are connected allowing the whole colony to benefit when one polyp captures food. During the day, most polyps are withdrawn into their skeletons. At night the colonies of polyps emerge and extend their tentacles to extract calcium from the seawater to build their skeletons, and to use their stinging nematocysts to capture tiny zooplankton delivered by marine currents.

The special relationship between the coral polyp and zooxanthellae



The zooxanthellae photosynthesise producing food (carbohydrate) and oxygen which is used by the polyp. The polyp also gets food from catching zooplankton from the sea. The waste products of the polyp are nutrients which are recycled by the zooxanthellae. The carbon dioxide produced by the polyp's respiration is used by the zooxanthellae in the production of carbohydrate during photosynthesis. In this symbiotic relationship the polyp gets food from the zooxanthellae, and the zooxanthellae gets a safe place to live with a constant supply of nutrients.

The coral polyps house the photosynthetic zooxanthellae within their tissues. It is the pigments from these zooxanthellae that give the corals their distinctive colours – usually subdued shades of brown, but also shades of purple, orange, blue, red and yellow. The zooxanthellae photosynthesise in daylight, producing carbohydrate and oxygen, both of which are used by the coral polyp – carbohydrate for food, and oxygen for respiration, allowing the animal to grow, reproduce, and secrete their calcium carbonate skeletons. In exchange, the zooxanthellae are permitted to live within the polyp's tissues, keeping them relatively safe.

As well as being housed, within the polyp's tissues, the zooxanthellae are constantly supplied with the nutrients (nitrogenous and phosphorous-containing material) from the polyp's waste products and the carbon dioxide produced by the polyp's respiration. These nutrients are essential for algal growth, and the carbon dioxide is needed for photosynthesis. Although tropical waters are typically low in dissolved nutrients (the only nutrients usually available to algae), nutrients are brought into the coral when the polyp feeds on zooplankton from the water column. The efficient recycling of nutrients in the polyp-zooxanthellae relationship allows the algae to survive in nutrient limited waters. In order to control the growth of the zooxanthellae, the polyps limit the supply on nutrients to the algae, and the polyps also secrete compounds that make the algal cells leak out carbohydrate leaving little for algal growth. This prevents the algae from multiplying excessively and outgrowing the polyps.

The co-dependent relationship between coral polyps and the algae within their tissues is critical for the survival and maintenance of coral reefs. Major changes in water temperature, the presence of sediment and the introduction of pollutants in the water can threaten this delicate symbiotic balance, thereby weakening and killing polyps and algae, and eventually destroying the living reef itself.

Coral reproduction

Corals reproduce in two ways – ***asexually*** (without eggs or sperm) and ***sexually*** (with eggs fertilised by sperm).

- Asexual reproduction occurs when the parent polyp buds or divides to form a daughter polyp, which is an exact genetic copy of the parent, with its tissues connected to the rest of the colony.

- Corals can also reproduce sexually by a process known as spawning. Spawning occurs when eggs and sperm are released into the sea. The sperm then fertilizes the eggs in the water, and a new individual, called a planula larvae, develops. A Planula larva is the free-swimming larval stage of a coral. Depending on the type of coral, the planula may drift in the sea for weeks to months. When it is time to settle (and conditions are right) the planula attaches itself to a vacant patch of reef and starts to grow into the founder (parent) polyp for a new coral colony.

Human benefit from coral reefs

In addition to being home to an enormous diversity of organisms, mankind benefits from coral reefs in a number of ways:

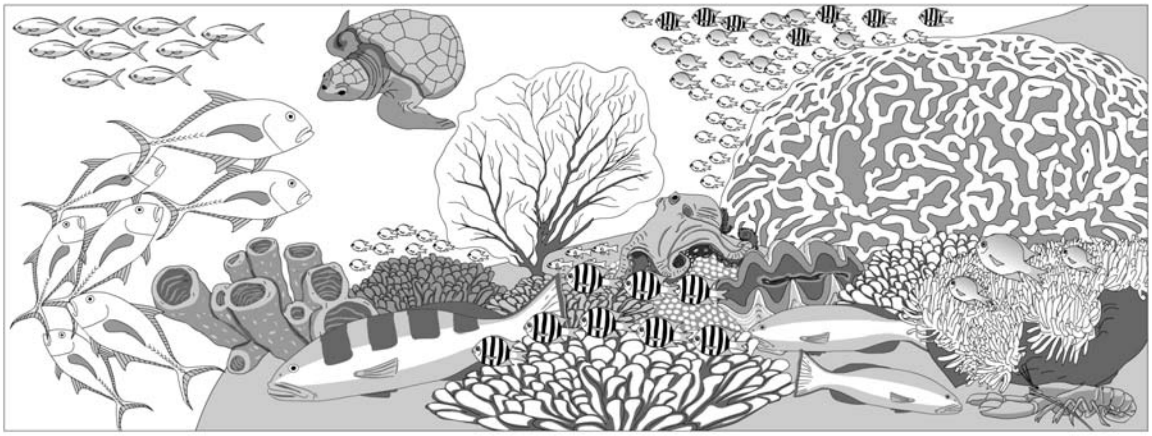
- Many organisms associated with the coral reefs are harvested by man for food or for trade. In this way, a lot of families living in the coastal tropics depend on coral reefs for their livelihoods and food.

- Coral reefs act as a barrier to large waves which have the potential to erode much land from the coast, keeping beaches and coastal communities intact.

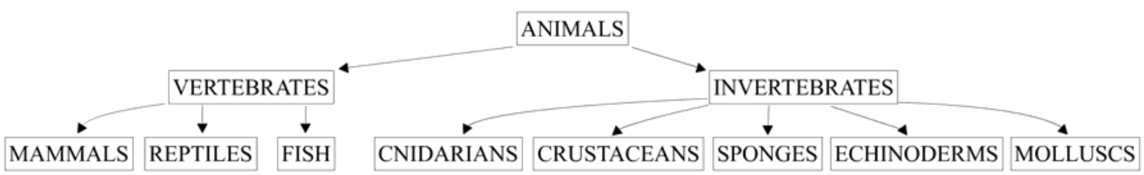
- Coral reefs are a large tourist attraction. A place to relax and enjoy snorkelling, diving and fishing. The economy of many countries with coral reefs depend on this tourism.

- Some coral reef organisms are studied as potential sources of medicines.

Animals found on coral reefs



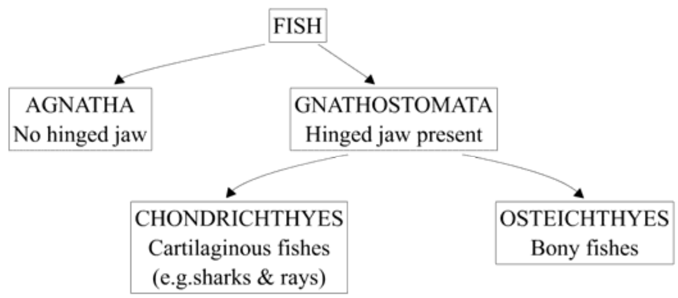
There are many different animals that live on or in association with coral reefs. These include ***vertebrates***- animals with vertebrae (backbones) - such as fish and turtles, and ***invertebrates*** – animals without vertebrae - such as crabs, lobsters, starfish, sea fans and the corals themselves.



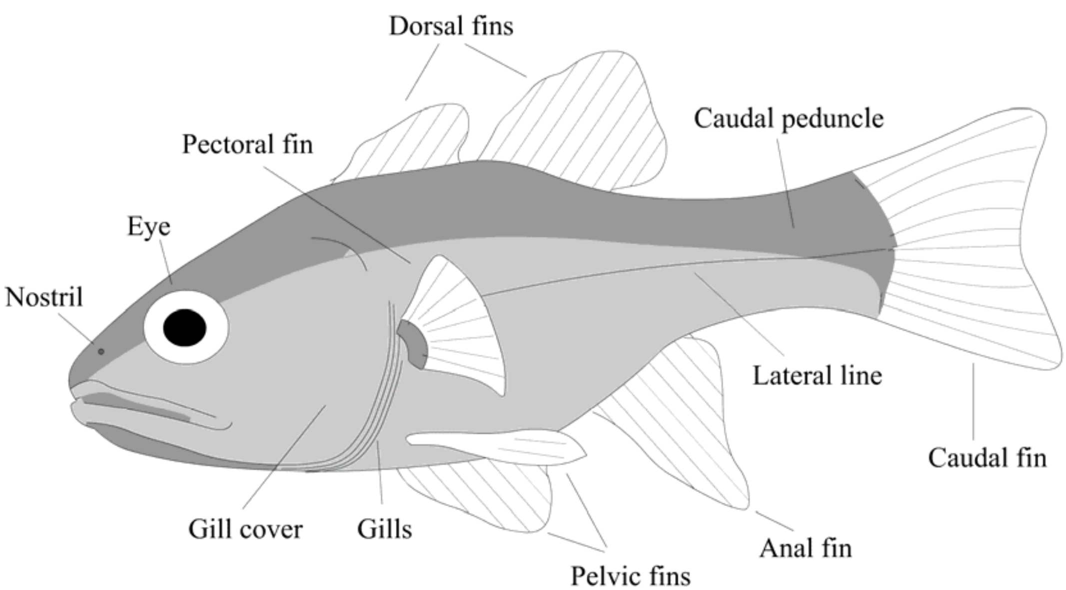
Marine vertebrates

Fish

Fish are cold-blooded vertebrates with median fins that are adapted to live in water. With few exceptions, fish get oxygen from the water via their gills. Scientists divide fishes into two major divisions, those with hinged jaws, Gnathostomata, and those without hinged jaws, Agnatha. The group with hinged jaws is further divided into those with cartilaginous skeletons, Chondrichthyes (e.g. sharks and rays), and those with bony skeletons, Osteichthyes.

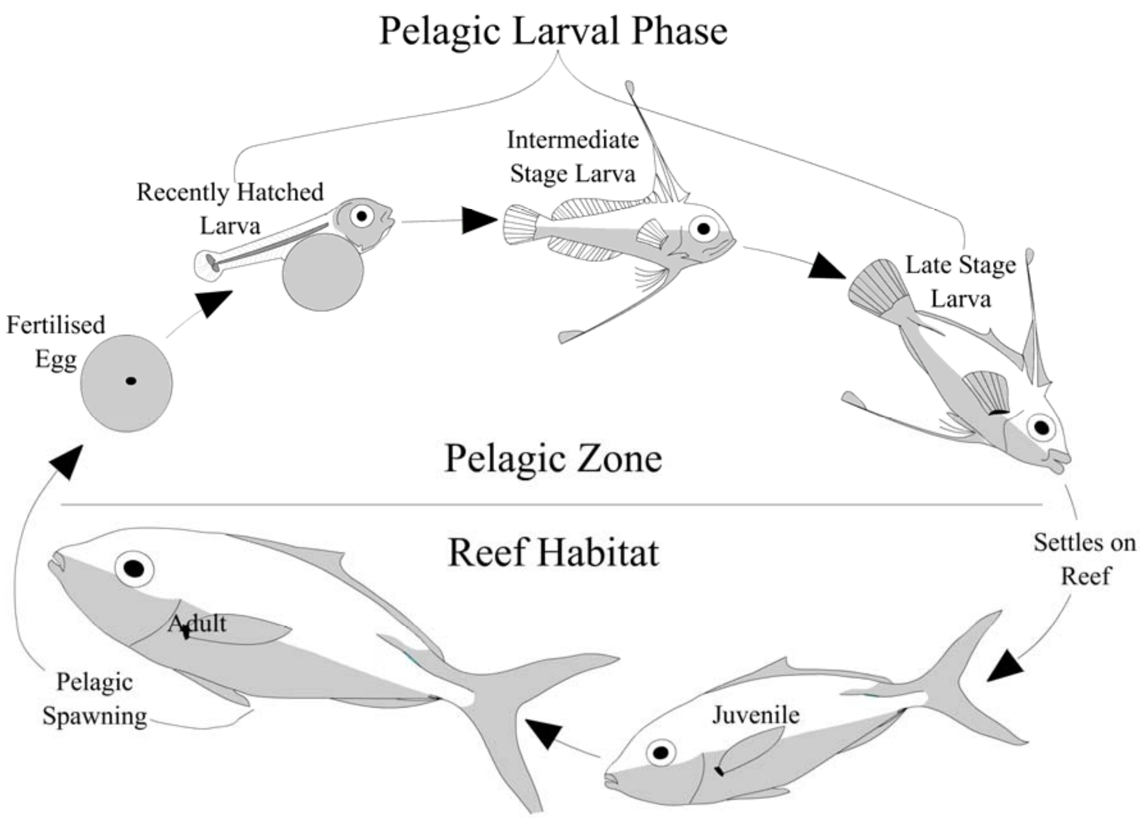


Physical features



Reproduction

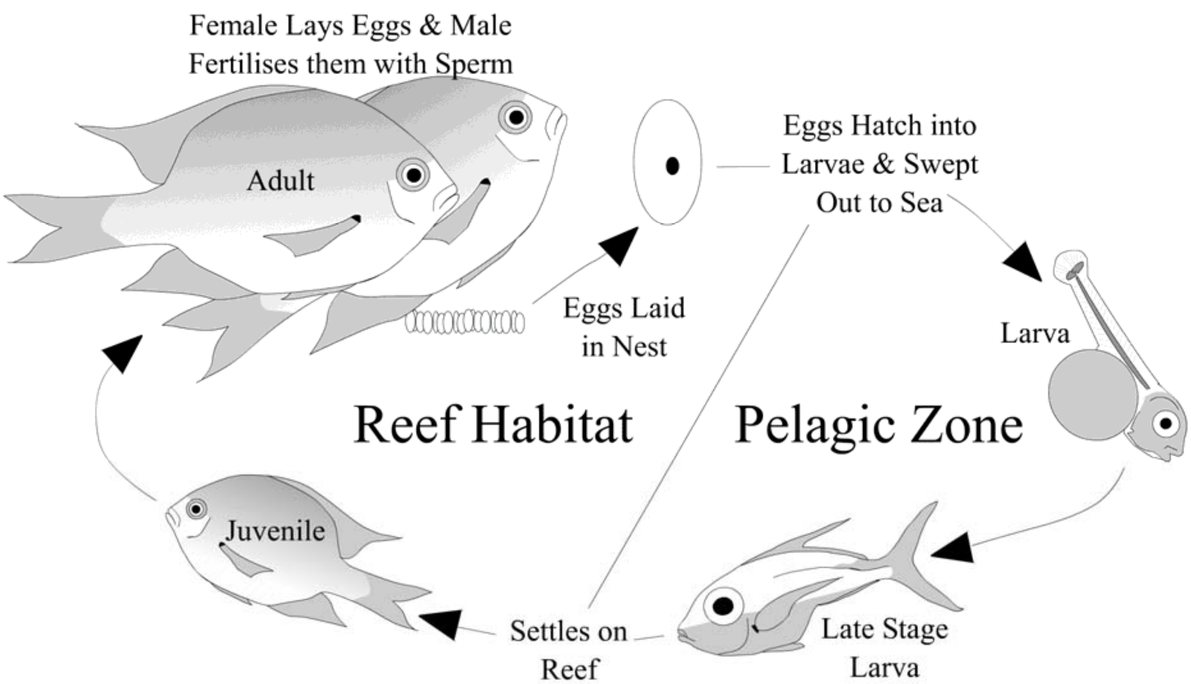
A lot of marine animals have a ***two part life cycle*** – the adults spend their life attached to or in association with a reef or the sea floor, but the larvae (and sometimes eggs) develop away from the reef in the open ocean. This stage is called the ***pelagic larval phase***. The pelagic zone is the open ocean. In the case of coral reef animals, once the larvae have reached a certain stage of development, they are ready to settle on the reef and metamorphose into juveniles, and then develop into adults, reproduce and release eggs and larvae of their own.



Fish reproduce in a number of different ways. Most fish lay eggs, either into a nest on the reef (***demersal spawners***) or directly into the ocean (***pelagic spawners***). In a few species the male scoops up the eggs and looks after them in his mouth until they hatch (***mouth brooders***). Some sharks and rays birth do not lay eggs, instead they give birth to fully formed young (***live young bearers***).

Demersal spawners

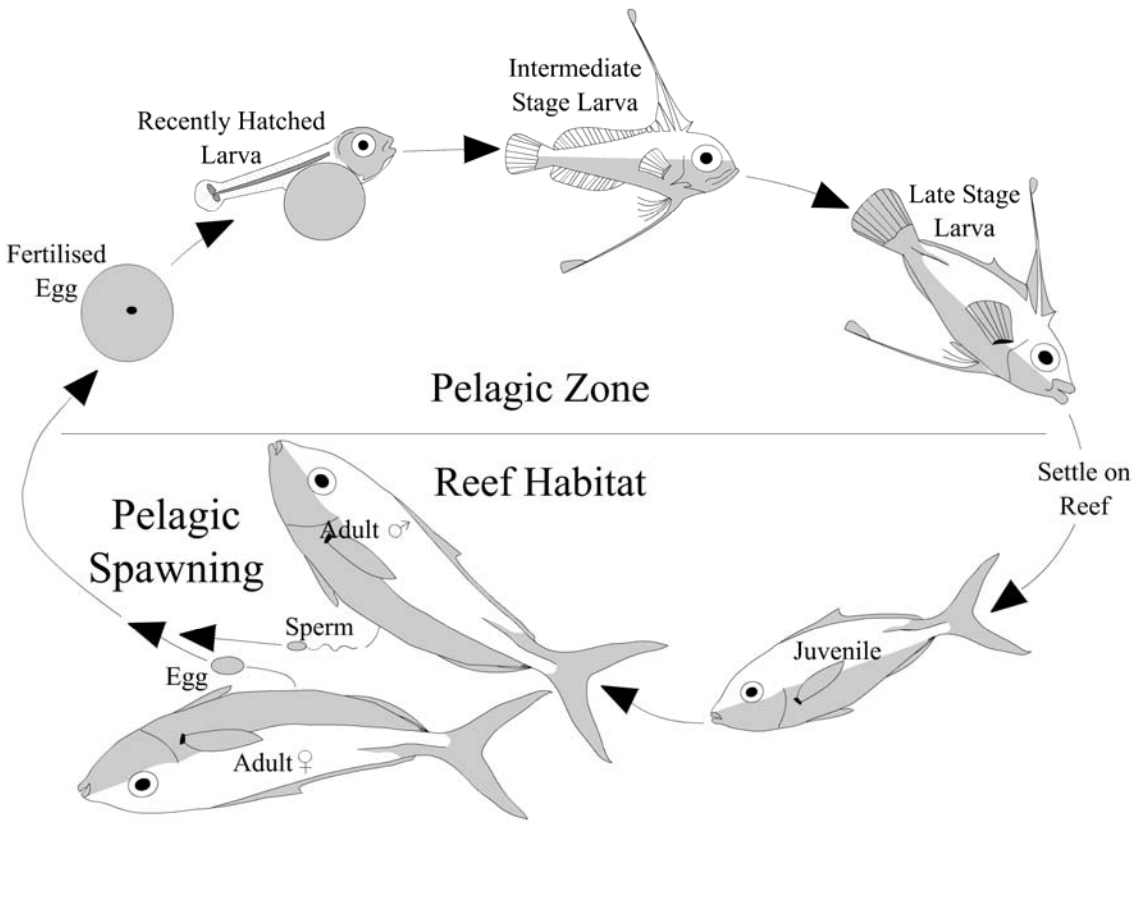
Most fishes lay eggs, which are fertilised externally by the male. In demersal spawning species the eggs are laid in a nest on the reef. The eggs looked after by the parents who protect them from being eaten by other animals. In many species it is the male that looks after and protects the eggs. Most species of reef fish that lay demersal eggs are small, except for the Titan triggerfish which can grow up to 60cm long and will aggressively defend its eggs from any animal that wanders too close to the nest. Once the eggs have hatched, the larvae drift off into the pelagic zone where they grow and develop for several weeks before returning to settle on a reef and develop into juveniles.



Pelagic spawners

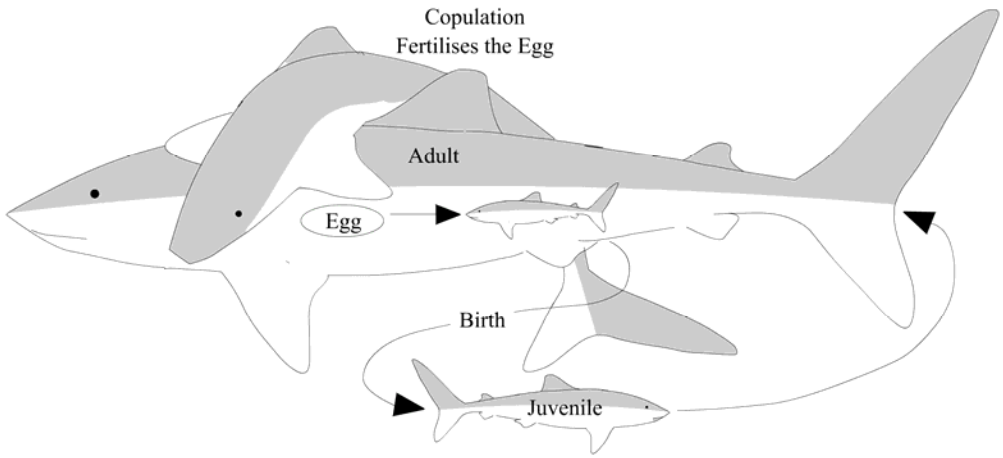
Most of the larger species of coral reef fish spawn pelagicaly. ***Pelagic spawning*** occurs when the female and male (sometimes more than one male at a time) rise quickly in the water column and release their eggs and sperm at the apex of this ***spawning rush***. The eggs are fertilised by the sperm and then drift off into the pelagic zone with the currents. The eggs hatch into larvae, which remain in the pelagic zone for a number of weeks. When they are sufficiently developed the larvae return to the reef and develop into juveniles.

Pelagic spawning is risky for two reasons: (1) the eggs are left in the water and can be preyed upon by any planktivore that comes into contact with them, and (2) during the spawning rush, the adults rise up away from the relative safety of the reef and expose themselves to potential predators.



Live young bearers

Fertilisation occurs by copulation and females give birth to live young much like in humans and other mammals. This mode of reproduction is rare in fish and mostly occurs in sharks and rays.



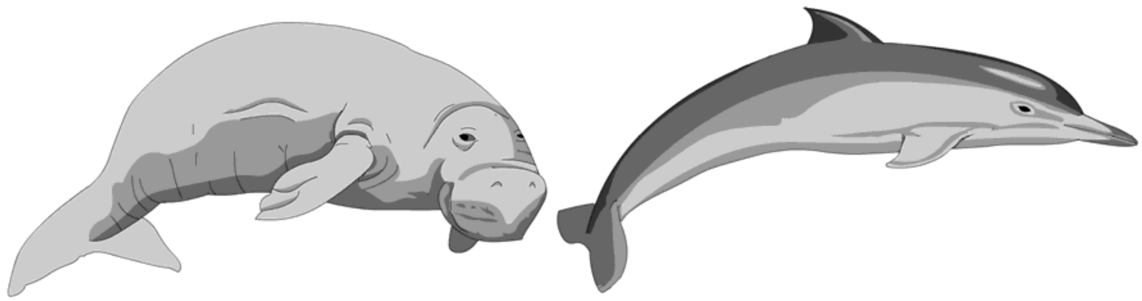
Spawning aggregations

Spawning aggregations are formed by a number of species of coral reef fish. Spawning aggregations occur when groups of fish migrate to the same location at the same time to spawn. They can be formed by more than 100,000 individuals. Spawning aggregations are often targeted by fishermen because the timing and location of spawning aggregations is highly predictable, and because larger numbers of fish can be caught there. Fishing spawning aggregations can cause catastrophic declines in fish populations because a large number of the breeding population are rapidly removed from the population. This seriously reduces the ability of the population to produce enough young to sustain future generations, leading to a collapse of the fishery. The ***live reef food fish trade*** poses an especially large threat to species that form spawning aggregations in the Indo-Pacific and Southeast Asia. This trade involves capturing coral reef fish from spawning aggregations, and keeping them alive whilst transported to Hong Kong, Singapore and Southern China until such as time as they are cooked in restaurants.

Sex change – hermaphroditism

Some coral reef fish spend part of their lives as females and the other part as males. This is called ***sequential hermaphroditism***. For example, many species of wrasse and grouper that start life as females and then change sex into males when they reach a large size. In contrast, the anemonefish starts off as male and changes sex into a female when it becomes the largest individual in the group.

Marine mammals



Marine mammals are warm-blooded animals that are adapted to living in the sea. Unlike fish, they do not possess gills and have to surface to breathe air through their lungs. Marine mammals include whales, dolphins, dugongs, and in temperate areas seals and sea otters. Marine mammals give birth to live young in the same way as terrestrial mammals: in order to reproduce, a male marine mammal copulates with a female and fertilises her eggs. The foetus develops in the womb, and the mother gives birth to the young following the gestation period. The mother then looks after her baby, feeding it milk from her mammary glands.

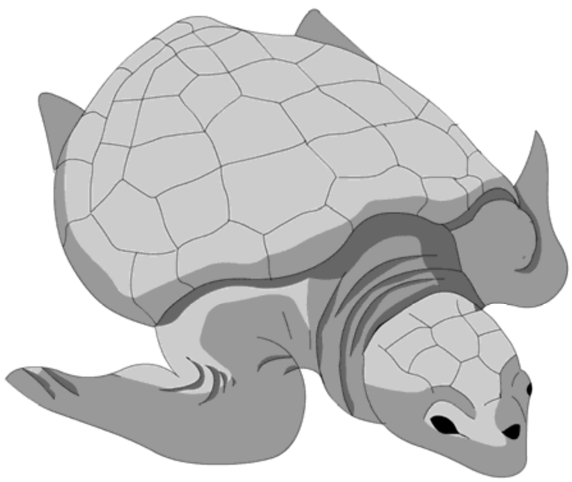
Marine mammals such as whales, dolphins and porpoises belong to a group called cetaceans. Superficially, cetaceans may look like sharks, but cetaceans are not related to fish and swim with an up and down motion of their flukes (tails), whereas sharks and most other fishes swim with a side to side motion of their tails. Some cetaceans can live for over 100 years – you can tell their ages by looking at the growth rings on their teeth in much the same way as you can with trees. They have smooth, sensitive and hairless skin. Blubber (fat) under the skin keeps them warm in the water.

Threats to survival

Humans have seriously reduced the numbers of whales and dugongs by hunting. Dugong have been traditionally hunted in many parts of the Pacific, but the growing human population is placing too much pressure on their populations. Dugong numbers are declining and they could disappear entirely if they are not protected from hunting and other impacts, such as loss of feeding areas and injuries from collisions with boats. Globally, despite restrictions on whaling, humans continue to have an impact on whale and dolphin populations. Even with improved fishing methods, many dolphins are still killed as a result of being trapped in tuna nets and anti-shark nets.

Marine reptiles

Turtle



Sea Krait

Marine reptiles are cold-blooded animals adapted to living in the sea. Like marine mammals, they do not possess gills, but have to surface to breathe air through their lungs. Marine reptiles include turtles, sea snakes and crocodiles. Reproduction occurs when a male and female copulate. In the case of true sea snakes, females give birth to live young in the sea, but other reptiles such as turtles, crocodiles and sea kraits (false sea snakes) lay eggs on land. The young return to the sea after hatching from the eggs. Female turtles lay their eggs in nests on sandy beaches at night.

Threats to survival

In many places throughout the world turtles are under threat. Adult turtles are hunted for meat and for their shells. Turtle eggs are consumed by humans and introduced predators. Coastal development can disrupt or prevent turtle nesting, and huge quantities of turtles are captured and killed accidentally by fishing nets.

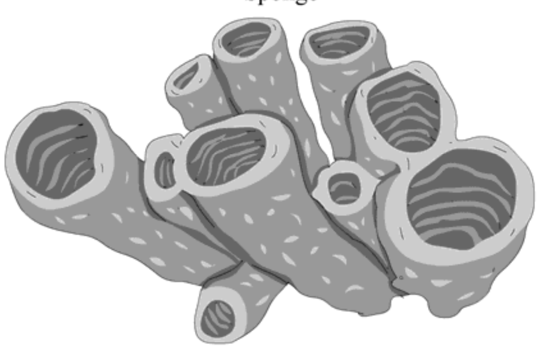
Marine invertebrates

Invertebrate animals comprise about 97% of all the different animals described by scientists throughout the world, both on land and sea. The great majority of invertebrates are insects. All invertebrates are cold-blooded with no mechanism to control their internal body temperatures. Body processes depends on temperature, which in these animals, is dependent upon the environment.

Internal and external skeletons:

Although invertebrates do not have a backbone, some invertebrates have structures within their bodies that help give them shape and form. For example, sponges have hard fibres and needles that help support their bodies and give them a solid shape. Many other invertebrates have ***exoskeletons*** (external skeletons). The type of exoskeleton they possess plays a large role in determining the degree to which they are able to move and thus the way they live. For example, prawns, shrimps and crabs have a partially moveable exoskeleton that allows them to move about quite freely along the bottom. Whereas the extremely hard-shelled oysters lives totally exposed and permanently attached to a solid area of substratum.

Porifera – sponges



Sponges are considered to be amongst the simplest and oldest living group of multicellular living organisms.

Body structure

- Skeletal support in sponges is provided by a network of hard spicules and flexible fibres. Spicules are small crystalline structures made from a range of compounds including calcium carbonate and silicate, while protein fibres produce the soft, classically spongy skeleton typical of many sponges.

- Sponges have a network of inhalent and exhalent canal. The inhalent canals originate as small pores on the outer surface of the sponges and lead to spherical chambers that pump water through the body in one direction. Food is filtered from the water pumped into the sponge. Oxygen is also absorbed from the water, which is then expelled from the sponge through one or several exhalent pores.

- Sponges vary greatly in growth form and size from thin encrusting sheets to large barrels.

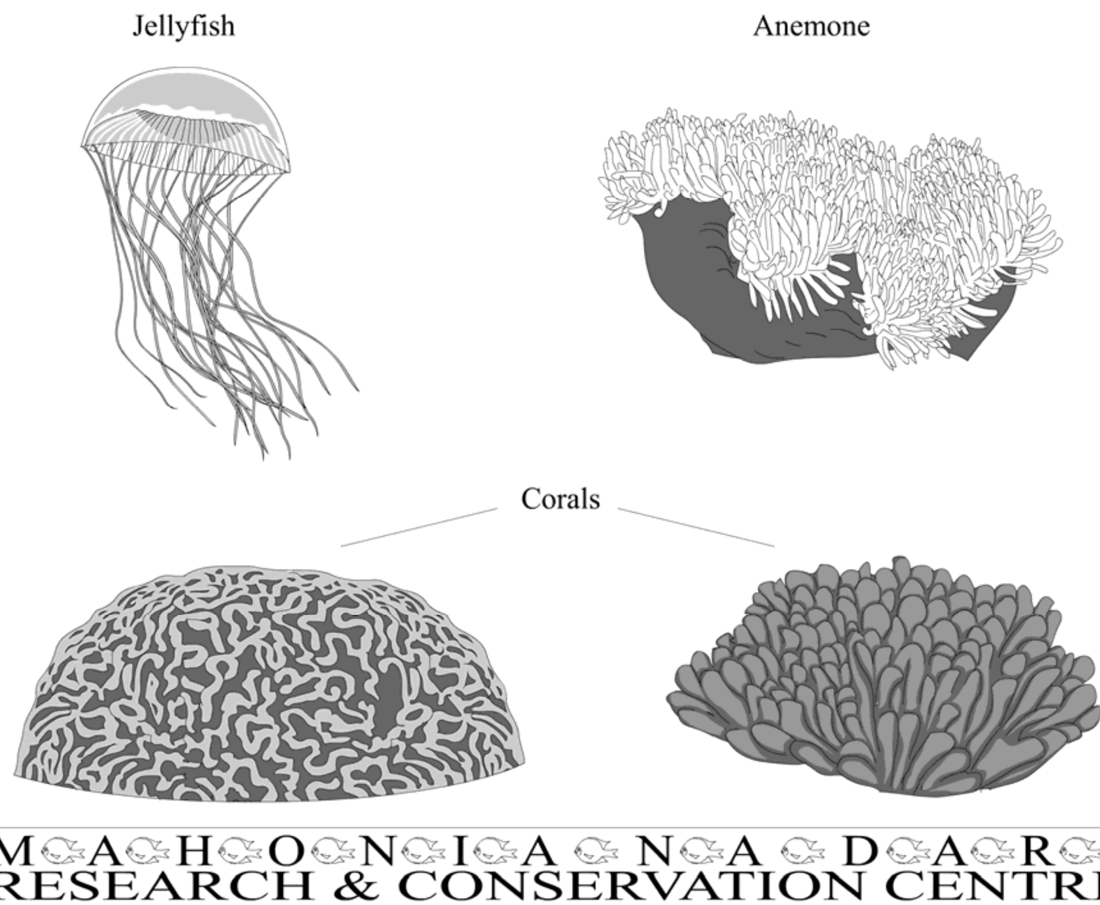
Importance

Sponges provide homes for a variety of animals including shrimp, crabs, barnacles, worms, brittle stars, sea cucumbers and even other sponges.

Sponges extract particles from the water, cleaning the water and recycling suspended organic matter.

Some sponges bore holes into other animals including corals, oysters and other molluscs. Boring sponges are responsible for a large amount of bio-erosion of the reef.

Cnidarians



Cnidarians include hydroids, jellyfishes, corals, sea anemones, gorgonians. They are also known as coelenterates, and are the most common invertebrates found in shallow waters.

Body structure

A central mouth surrounded by tentacles, a single opening through which food is ingested and expelled, a jellylike middle layer and intracellular (within the cells) stinging structures called nematocysts.

This group of animals includes the many species of corals that form the basis of tropical reef ecosystems. Apart from the jellyfishes and seawasps, cnidarians are sessile (do not move) organisms, usually cemented to the substratum in some fashion.

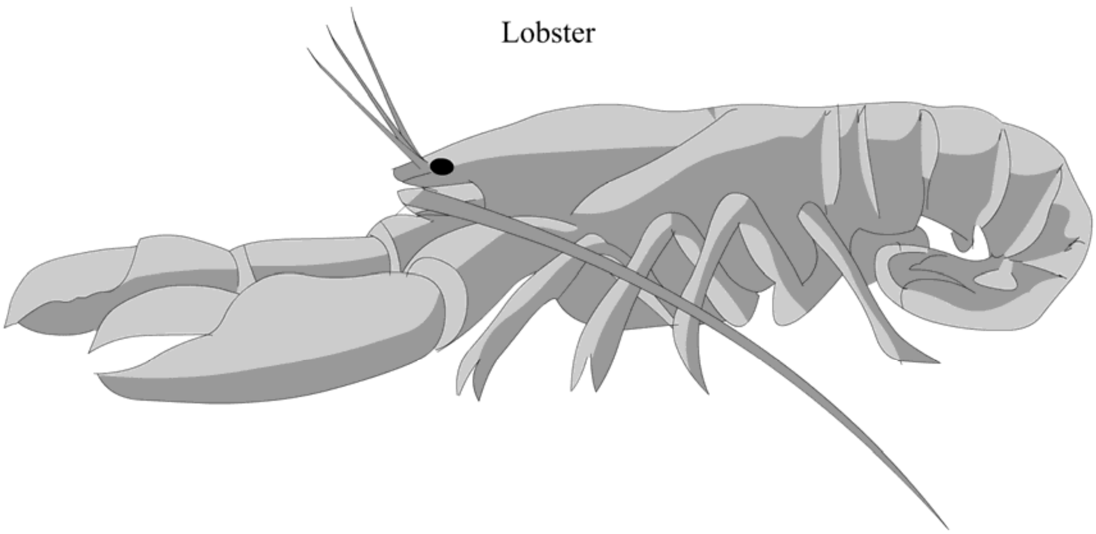
There is fierce competition for space on most coral reefs between the corals and other attached reef organisms. In clear tropical waters, corals dominate other sessile invertebrates and cover large areas of available substrate. These stony corals fall into three general categories, including the branching corals, massive corals and plate corals, each with particular advantages when it comes to occupying space on the reef:

- ***Branching corals*** are the fastest growing but are relatively fragile, prone to destruction by storm waves and surge.
- ***Plate corals*** are slower growing, but their flattened plate structure allows them to capture light in deeper areas and to grow over nearby corals, cutting off their competitors' light.
- ***The massive corals***, brain and star, form large heads and clumps reaching ten feet high, but these are the slowest growing. They have the advantage of being the strongest and most resistant to storm damage.

Danger

Most cnidarians can cause a painful sting from their nematocysts.

Crustaceans



Crustaceans include crabs, lobsters, shrimps, and barnacles. They have hard external skeletons, and for many of them (e.g. crabs, lobsters and shrimps), growth is only possible by periodically shedding these skeletons and growing new, bigger ones. In the case of crabs, lobsters and shrimps, reproduction occurs when a male gives the female a packet of sperm to fertilise her eggs. The fertilised eggs are carried on the belly of the female until they hatch into larvae and then enter their pelagic larval phase. Once a series of larval phases have been completed in the pelagic zone, the late stage larvae are ready to settle on a reef, and develop into juveniles, which will then grow into adults. As barnacles are attached to the substratum and are not able to move, the males have extraordinarily long penises so they can fertilise neighbouring females. Proportional to their body sizes barnacles have the biggest penises of any known animals.

Human consumption

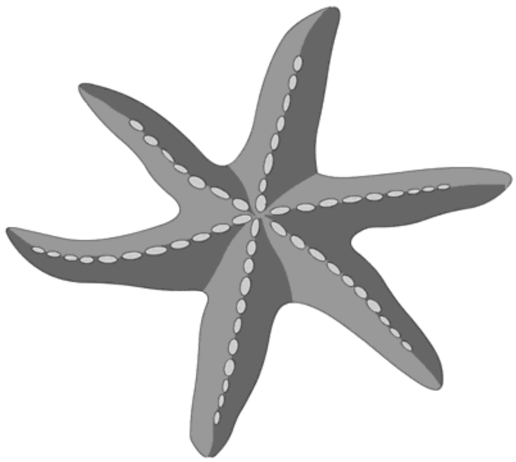
Many crustaceans are eaten by humans, and form the basis of important fisheries: e.g. crabs, lobsters, prawns.

Cleaner shrimps

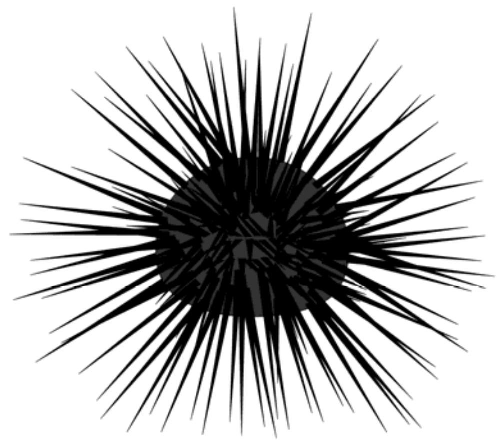
Cleaner shrimps along with their fish counterparts (cleaner wrasses) perform important roles on coral reefs. These animals feed on the ecto-parasites (parasites on the outsides of animals) of coral reef fish. Fish allow these animals to explore their bodies for parasites and remove them. Without cleaner shrimps and wrasses, fish would suffer from high parasite loads. These cleaning animals are so important that large predatory fish do not eat them, but rather it is not uncommon to see these fish resting motionless with their mouths open whilst cleaner wrasses explore the insides of their mouths and gills for parasites.

Echinoderms

Starfish



Sea Urchin



Echinoderms include starfish, sea urchins, sea cucumbers, and feather stars. Apart from the sea cucumbers, most other echinoderms display a penta-radiate symmetry, that is to say they have five (or a multiple of five: 5, 10, 15, 20…) arms. In the case of sea urchins, the test (the hard shell from which the spines and tube feet protrude) has five roughly symmetrical divisions. Echinoderms are widely distributed in benthic habitats from the intertidal zone to the deep sea.

Water vascular system

Echinoderms possess a unique water vascular system, which consists of a series of canals that radiate throughout the body and terminate in structures called tube feet. The tube feet penetrate the body wall and often have a tiny suction or adhesive cup at the end. Tube feet serve echinoderms in a variety of ways including adhesion, locomotion, feeding and respiration.

Feeding

Feather stars and sealillies are filter feeders using their arms to capture food particles and plankton from the water that they then pass to their mouths. Most cling to the reef surface with modified arms called cirri. Some of these filter feeders climb to exposed positions on gorgonians and reef structures at night in areas of currents to capture plankton more effectively. Starfish are typically predators or detritus feeders

Danger

Many echinoderms possess sharp spines. Some of these spines are toxic, such as those of the crown-of-thorns and penetration by these results in a painful wound.

Human use

Some sea cucumbers, anemones and sea urchins are harvested for human consumption.

Importance to coral reefs

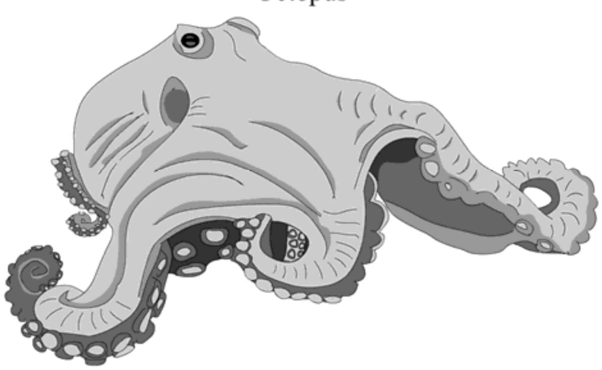
The sea urchins are major grazers of the reef's surface. They crop algae growing on reef substrate with their five-toothed feeding structure (Aristotle's lantern). Without their grazing and that of other herbivores (such as parrotfish) reefs would be more dominated with algae at the expense of coral.

Echinoderms that feed on organic material in the sand pass a great amount of material through their guts and, by doing so, help turn over and clean reef sediment. Many sea cucumbers feed in this fashion, passing pelletised excreta back on to the reef.

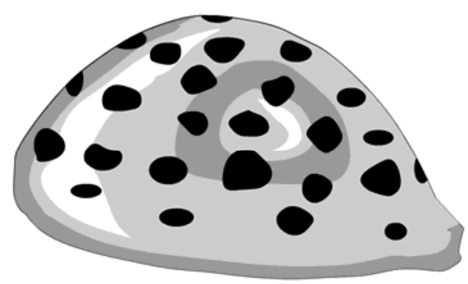
Echinoderms can also be predators on molluscs and other invertebrates. For example, the crown-of-thorns starfish eats corals and can cause the degradation of large areas of reef.

Molluscs

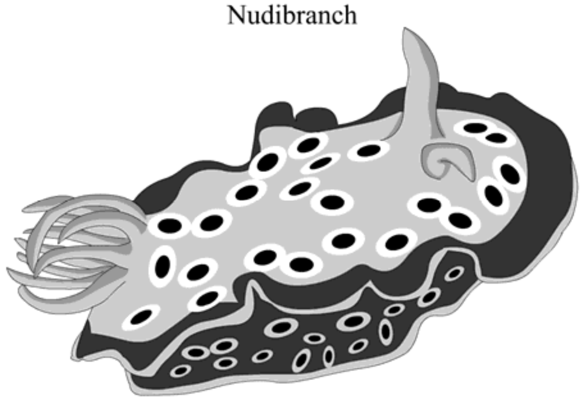
Octopus



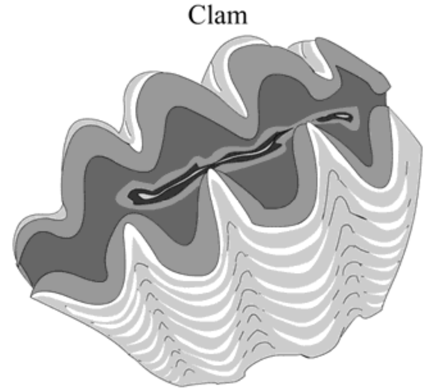
Cowrie



Nudibranch



Clam



Molluscs include the ***cephalopods*** - octopuses, squid, cuttlefish, and nautiluses, the ***gastropods*** - trochus snails, nudibranchs, cowries, coneshells, and conches, and the ***bivalves*** - clams, mussels, oysters and cockles. The diversity of molluscan species reflects their great success in adapting to many different habitats and lifestyles.

Body Structure

- Although the molluscs appear to come in many different forms, they derive from the same body plan. The body is typically divided into a head, with well-developed sensory organs, a large soft internal mass, and a muscular foot that is commonly used for crawling.

- Cephalopods can take in water, expel it from their mantle cavity and spurt forward by means of jet propulsion, in addition to their ability to crawl forward with their well-developed tentacles.

- In sessile forms, such as oysters, the muscular foot is greatly reduced.

Most molluscs possess an external calcareous shell. Evolutionary changes in some groups such as nudibranchs, squids and octopi, has resulted in reduction, internalisation, or complete loss of the shell. These species have developed other means of protection and evasion. For example, the octopus confuses predators by emitting a cloud of ink and many nudibranchs have toxins in their bodies that are poisonous to predators

- Chitons are flattened with eight overlapping plates comprising the shell, surrounded by a girdle. Most are intertidal and shallow subtidal, and have a large foot by which they clamp down to rock so tightly that they cannot be moved. Most feed on algae grazing the surface of rocks, while a few also feed on various encrusting invertebrates. They are generally slow moving animals.

- Snails and slugs usually have shells, however in some species it is reduced or absent. Shells are made of calcium carbonate secreted by the mantle. Many species have a trap door that helps to seal the entrance to the shell when the animal has withdrawn inside. Most have large fleshy feet, which are used for locomotion over a variety of substrate, propelled by either ciliary action or waves of fine muscular contraction along the surface of the foot. Mucous secreted by the foot helps the animals to glide over the substratum. The shape of the shell indicates a lot about the lifestyle of the animal: a spiny shelled animal usually inhabits soft, muddy bottoms, while a low, broad shelled animal is suited to a high wave action habitat because its shell offers less resistance to water motion.

Feeding

Most snails have a unique file-like mouthpart called a radula. Herbivorous species use this to rasp or cut algae from rocks. In carnivorous coneshells, the radula is modified into a barbed, harpoon-like structure, which they use to inject a powerful toxin into their unsuspecting prey, usually other molluscs.

Importance

Molluscs form the basis of many economically valuable fisheries. Squids and octopi are fished throughout the world. Various oysters produce both natural and cultured pearls with the shell of the blacklip pearl used in the production of buttons. Many bivalves are highly prized food items like the oysters and giant clams, as are gastropods such as the Caribbean queen conch and other large snails and limpets.

Biological Control

The trumpet triton shell is well known for its ability to kill and eat the crown-of-thorns starfish. This gastropod is one of the few predators of this venomous echinoderm, which has caused degradation on reefs in many parts of the tropical Pacific.

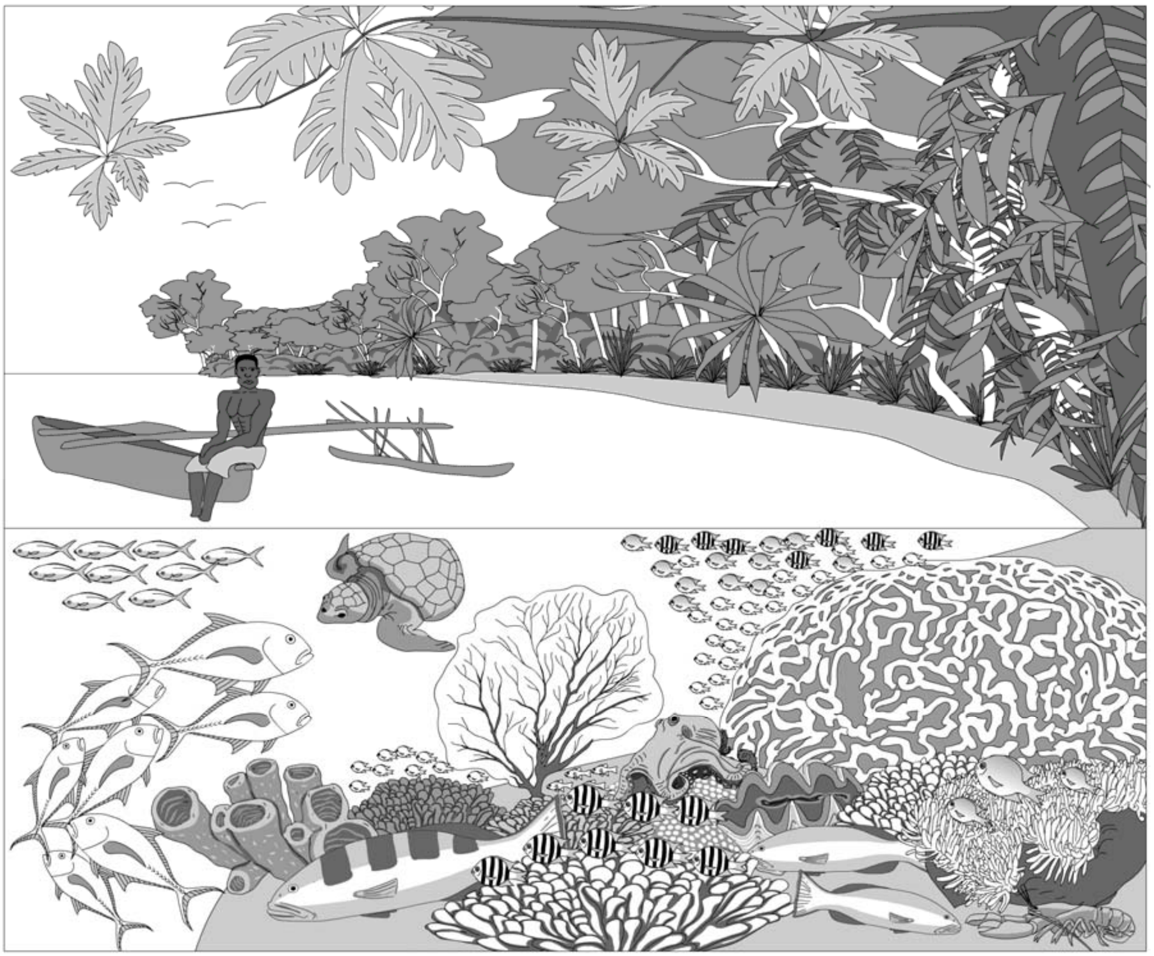
Danger

The venom of the blue-ringed octopus can be fatal to humans. All octopods have a beak capable of inflicting minor wounds, and the blue ring octopus has a poisonous bite capable of killing humans.

Some species of cone shells have a neurotoxin venom that can prove fatal to humans.

Part 2

Threats to coral reefs, conservation & management



PART 2: THREATS TO CORAL REEFS, CONSERVATION & MANAGEMENT

Threats to coral reefs

Despite the fact that coral reefs have persisted for millions of years and coped with changes in sea level and large fluctuations in water temperature, coral reefs are fragile environments threatened by many human activities. The following sections will outline the stresses that coral reefs are put under from natural processes and human activities.

Sustainability

The concept of ***sustainability*** is essential to conservation. Sustainability allows the exploitation of environments at levels that cause no long-term harm. For example, if logging is sustainable, then the removal of trees from forests will not harm the overall function of the forest. The other animals and plants that live in the forest will not be put at risk by the logging. In sustainably logged forests, the rate of growth and replenishment of the forest is equal to or greater than the rate at which trees are removed. Sustainable logging will also have no impact on other ecosystems like the rivers, lakes and seas to which the forests are connected by water movement. Actions that compromise this sustainability will jeopardise the persistence of healthy ecosystems.

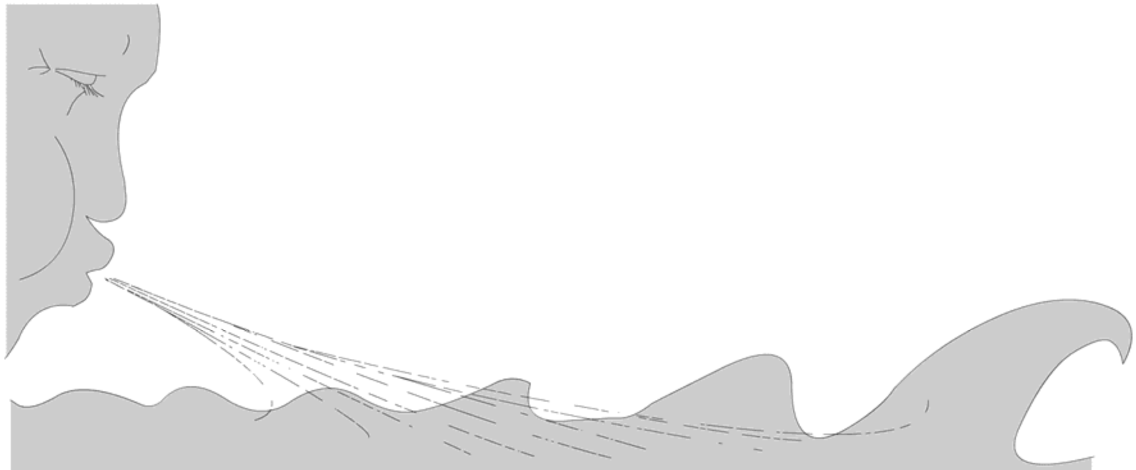
Natural impacts on coral reefs

Coral reefs are dynamic ecosystems. The physical structure of coral reefs changes over time as corals grow, die, and become replaced by other corals. Coral reefs are periodically impacted by natural phenomena such as hurricanes or cyclones and crown-of-thorns starfish infestations. These natural impacts can damage or kill many of the corals on a reef. However, the reef then begins to recover as new corals become established, grow and start to shape the new physical structure of the reef. When the next natural impact occurs on the reef the cycle of recovery starts again. In this way, coral reefs are constantly recovering from such impacts.

Natural phenomena that impact coral reefs include:

- Cyclones and storms
- Natural fluctuations in seawater temperatures
- Heavy rains that dilute salinity
- Extreme low tides that dry coral out
- Diseases
- Predator population explosions (e.g. Crown-of-thorns starfish)

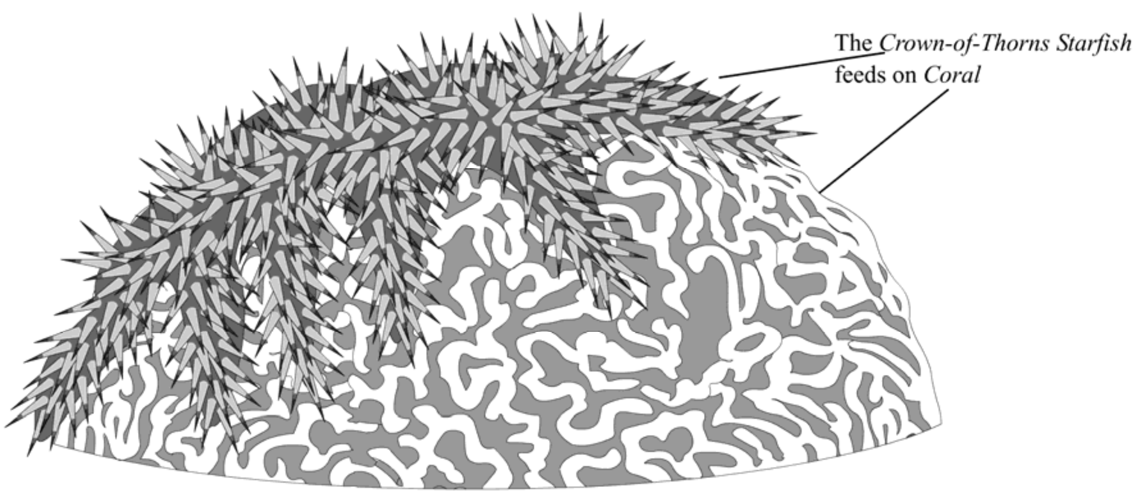
Cyclones and storms



Most of the world's coral reefs exist in areas prone to cyclones (hurricanes and cyclones are exactly the same phenomena, only occurring in different areas of the world). Most coral reefs are periodically impacted by hurricanes or cyclones, but provided enough time elapses between the damage caused by cyclones, reefs are usually able to recover and survive.

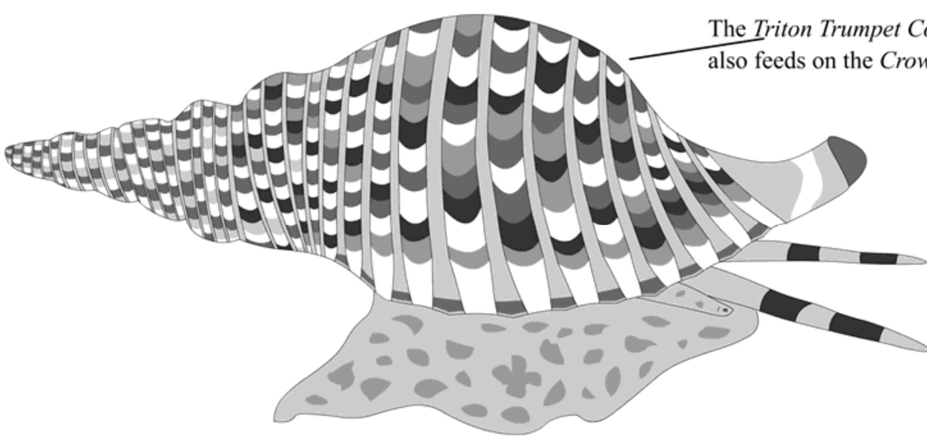
Coral reefs protect coastal areas from the damaging effects of storms, hurricanes and cyclones. Without coral reefs, many tropical islands would be washed away by the waves and rough seas formed when hurricanes and cyclones pass through.

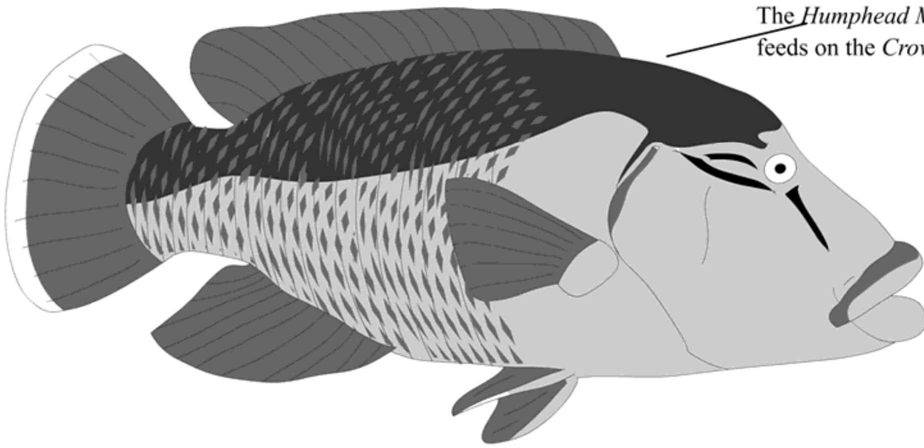
Crown-of-thorns starfish outbreaks



The Crown-of-thorns starfish feeds on the polyps of stony corals. It has sixteen arms each covered with prickly spines, and has the largest mouth relative to body size of any known animal. This starfish eats the coral, leaving only a white skeleton on the area of coral where the crown-of-thorns was feeding. This starfish usually exists at low population densities on coral reefs, and although killing corals, or parts of corals, the overall impact on a coral reef of the crown-of-thorns at low densities is negligible. However, periodically, the crown-of-thorns undergoes population explosions. Such high density infestations can eat most of the living coral on a reef. Within the space of two and a half years, thousands of crown-of-thorns destroyed almost all the living coral along a 38km stretch of reef surrounding the Pacific Island of Guam. Once the crown-of thorns has eaten all the coral tissue on a reef, the population declines as the starfish usually dies off, being unable to find food, unless able to move on to a nearby reef.

In recent years the number of recorded crown-of-thorns outbreaks has been increasing. Some scientists believe that human activities are responsible. Part of the problem might be that two of the main predators of the starfish, the Triton cone shell and the Humphead Maori wrasse, have been over-harvested. The Triton cone shell has been eradicated in many locations in the Indo-Pacific by shell collectors. The number of Humphead Maori wrasse has declined and on most reefs because of over-fishing for human consumption, and this fish no longer exists on many Indo-Pacific reefs. The removal of these predators may have helped the starfish's populations to rise to unnaturally high levels. Other scientists believe that population explosions of crown-of-thorns have always occurred in the past and are part of a natural cycle.





Reefs can usually recover from the seemingly disastrous attacks of crown-of-thorns starfish if human-caused stresses do not hinder the recovery process, and if sufficient time elapses between outbreaks.

Natural impacts can promote biodiversity on coral reefs

Despite the physical damage caused, the natural phenomena impacting coral reefs are actually believed to enhance the reefs' biodiversity. The fastest growing corals have a tendency to out-compete both the slower growing corals and other benthic organisms also unable to compete. Eventually, the reef benthos will become dominated by only a few species of coral. The diversity of organisms on coral reefs is supported by the physical complexity of the reef structure and the biological diversity that forms this structure (i.e. the corals, sponges, gorgonians etc.). If the reef is dominated by only a few species of coral then the reef loses much of its structural complexity. Organisms that depend on certain species of coral or other benthic organisms will not be able to persist if the organisms upon which they depend are no longer present on the reef. In short, the fewer species of coral, the fewer the number of species of other organisms the reef is able to support. However, these faster growing corals are usually less able to tolerate natural impacts such as hurricanes, cyclones and high sea temperatures. Natural disturbances, like storms, allow the poorer competitors to survive and promote a more structurally and biologically complex habitat, which enhances the diversity of life found on reefs.

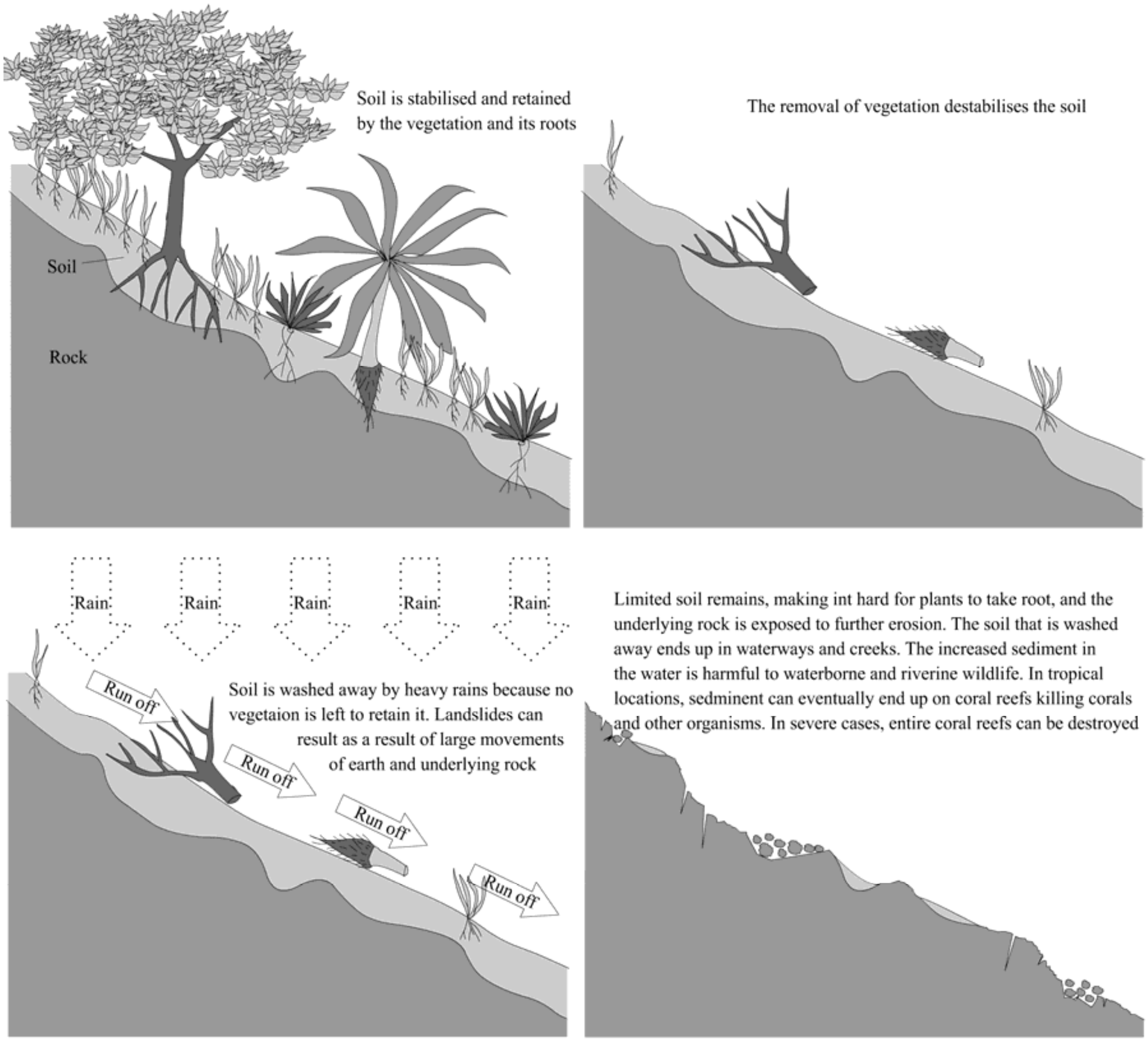
Human impacts of coral reefs

Humans are the biggest threat to coral reefs. Humans damage reefs and reef ecosystems directly through overfishing and destructive fishing practices, and indirectly through activities conducted on land.

Land based activities

The land and sea are inextricably linked by coasts, rivers, winds and man. Therefore, it is not surprising that many of the activities that occur on land end up affecting marine ecosystems. This section outlines some of the land based activities that affect coral reefs, what effects these activities cause and how to prevent or limit them from occurring.

Deforestation and sedimentation

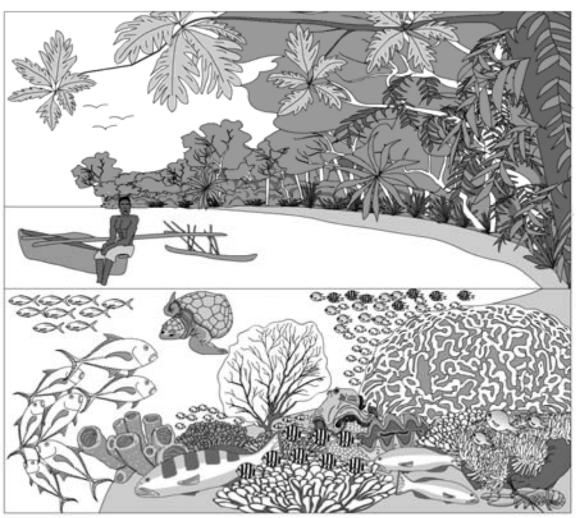


It is important that terrestrial ecosystems remain healthy so that the plants and animals they support can persist. The decline of terrestrial ecosystems and the loss of the organisms they support not only affect man directly, through loss of replenishable sources of food, building materials and even medicines, but also affects other ecosystems to which they are linked. For example, plants helps to stabilise the soils in which they grow. The roots collect and hold particles, preventing them from being washed away by rains or blown away by winds. The retention of soils by vegetation is important for a number of reasons:

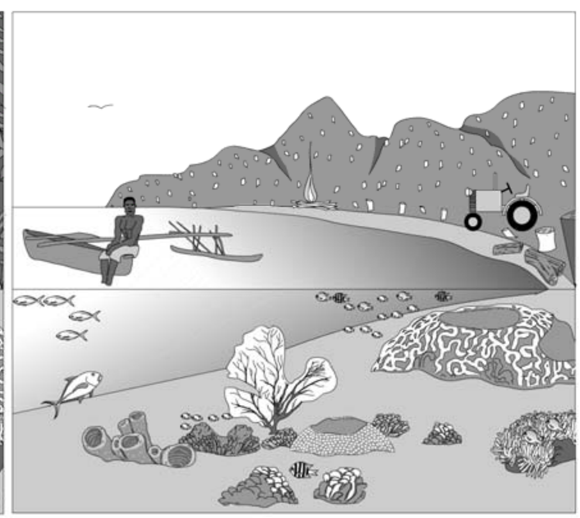
- Many plants need good soil cover in order to grow. Soil loss will prohibit a number of species from existing.
- Some animals need soils in which to live.
- If soil is not retained by vegetation, it will be washed away by rains or blown away by winds. This material will end up in streams, rivers, lakes and in the sea where it can damage aquatic life, a process called ***sedimentation***.

In locations where the terrestrial landscape has not been altered excessively by human activity, low levels of sedimentation can be tolerated by aquatic ecosystems. However, the excessive removal of vegetation by man has increased the amount of sediment being swept in into rivers, lakes and on coral reefs. This additional sediment is damaging the plants and animals that live in these areas.

Forests are cleared in many parts of the world for agricultural, industrial, mining, logging and residential purposes. The removal of forests is referred to as ***deforestation***, and represents the severest form of vegetation loss. Deforestation can lead to very large increases in the level of sedimentation experienced by aquatic ecosystems and can result in the loss of freshwater and marine life.



Healthy coral reef and rainforest prior to deforestation



Deforestation destroys the rainforest and causes sedimentation which destroys the coral reef

The levels of sedimentation that accompany land-clearing activities can be dramatically reduced by the inclusion of ***buffer zones***. Buffer zones are areas of natural vegetation that border streams, rivers, ponds, lakes and the coastline. Buffer zones are left around these water courses in order to help trap the sediment that is washed away from the land that has been cleared, preventing the sediment from ending up in the aquatic environment.

Pollution

Pollution is any unnatural addition to air, water, soil, or food. Pollution usually has a negative impact on the health, survival or activities of humans and other living organisms. Whilst much pollution comes in the form of chemicals and other materials, pollution can also take the form of unwanted energy emissions, such as excessive heat, noise and radiation. When resources such as minerals are extracted and processed waste products are produced which are often released into the atmosphere (as gases) or into water courses (as solid materials, as liquids, or dissolved in the water itself).

A **pollutant** is the chemical or material (solid, liquid or gas) that is causing the **pollution**.

The impacts of pollution

Pollution spoils the natural environment in various ways, damaging natural habitats and affecting human (and other animals') health. Some pollutants spoil the normal growth and appearance of the natural environment, while others spoil the air we breathe, the food we eat, water we drink or damage our health in some way, such as the birth deformities caused by nuclear radiation exposure or illnesses associated with inadvertent exposure to dangerous chemicals leaked into the environment.

Human activities polluting coral reefs

Sewage

Untreated sewage being released into rivers or the sea is a serious source of pollution. Sewage increases the quantity of nutrients, which eventually leads to the growth of bacteria that uses up most of the oxygen dissolved in the water. This can harm or kill the animals and plants in the water because they are dependent on this dissolved oxygen. The bacteria itself may be harmful to swimmers and those eating animals caught in the water. The degree of pollution may be measured by the consumption of oxygen or the ***biological oxygen demand*** (BOD) – the higher the BOD, the more polluted the water.

High nutrient levels encourage the growth of algae. On coral reefs, algae high nutrient levels can cause algae to grow excessively and overshadow corals. Corals become less able to compete for space, being replaced and overgrown by algae. As the reefs become dominated by algae rather than live coral, they lose much of their structural complexity, and the diversity of others animals on the reef decreases dramatically.

The high abundance (or blooms) of ***phytoplankton*** – tiny drifting aquatic plants - may turn the polluted water green. In some cases, these blooms produce poisonous by-products. These by-products can accumulate up the food chain causing seafood to become poisonous.

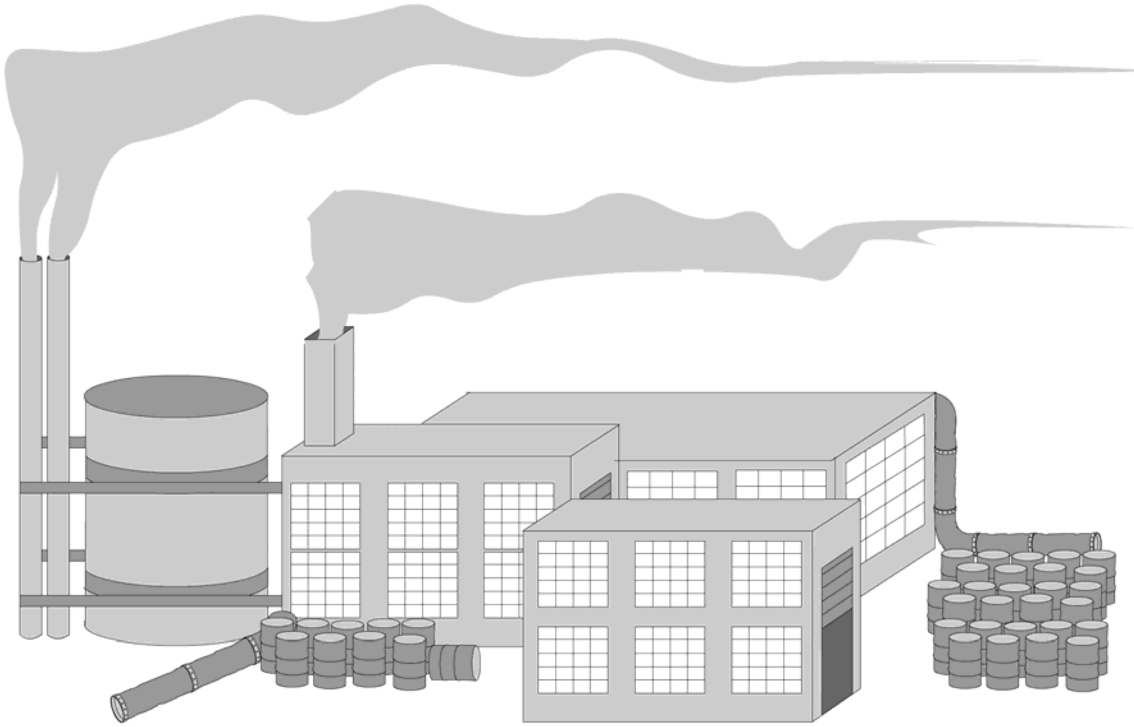
Mining & forestry

Forest trees are continually being logged for local use and export. Deforestation occurs as a result of excessive logging and clearing land for mining and agriculture. Such deforestation can lead to erosion, landslides and large amounts of sediment being washed into rivers, lakes, and into the sea where it can smother coral reefs. In addition to increases in sedimentation, mining creates wastes that are toxic to animals and plants. Coral reefs can be damaged if these wastes are washed into the water system along with the sediment.

Agriculture

Apart from the sedimentation caused by land clearing, another potential problem is the over-use of pesticides and fertilisers. When it rains these chemicals are washed off the land into rivers and coastal waters. Pesticides in water are particularly harmful to the young and larval stages of marine species, whilst the nutrients in fertilisers promote enhanced algal growth, which can overgrow and kill corals.

Industry



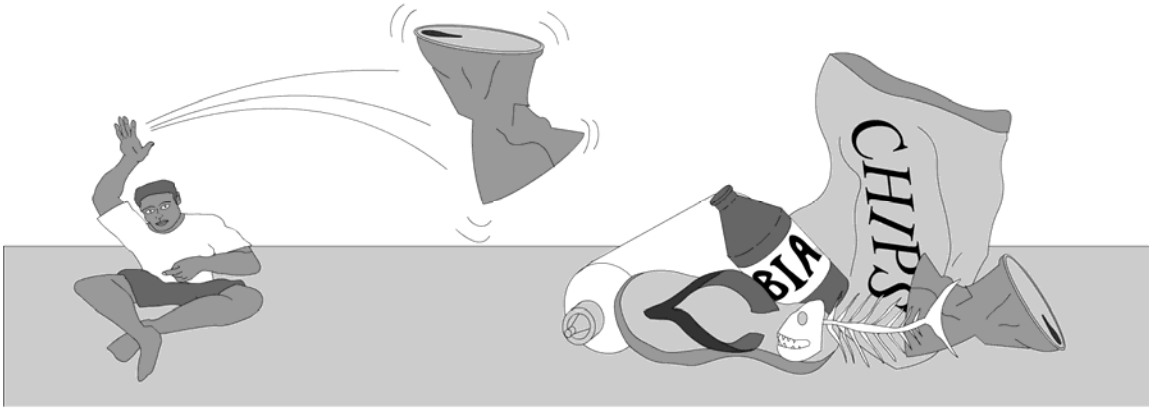
Several types of industries such as sugar mills, engineering plants, and fish and fruit processors discharge their wastes directly into coastal waters. Serious industrial pollutants are –

Cyanide, Copper, Zinc, Lead, Mercury

Some of these metals are particularly dangerous because they are cumulative: that is, even small amounts in water, will, over a long period, become concentrated in the tissues of marine animals. Large carnivorous fish may gain even higher concentrations as the toxins accumulate up the food chain and can be extremely if these animals are consumed by human beings.

Although less toxic, oil is a serious pollutant released by land-based activities and by ships. Oil forms a thin film on the surface of the water and can kill corals and intertidal animals attached to the rocks.

Dumping rubbish



In many areas of the Indo-Pacific people do not have a good understanding of the effects that rubbish can cause to the natural environment. There is a good reason for this: traditionally, most goods came from natural products and if wrapped, were bound in banana leaves and carried in woven baskets. All "packaging" was natural material, and when the goods and packaging were no longer needed, they were thrown away. Being made of plant or animal material, and thus biodegradable, it didn't matter where these objects were discarded because they would decompose quickly and have negligible impacts on the environment. Modernisation has brought "better" packaging - plastic bags, plastic and glass bottles, tin cans and non-perishable goods. Although most packaging and some goods are non-biodegradable, the same attitude exists – once something is no longer needed, it is thrown away with no regard to where it may end up. Sadly, this synthetic material does not decompose quickly and its effect on the environment is considerable. Animals can become ill and die after eating carelessly discarded objects such as plastic bags, bottle caps and cigarette butts. A lot of discarded rubbish is washed away into streams, rivers and into the ocean where it damages and kills aquatic life. Corals can be smothered and killed by rubbish whilst many different sorts of marine animals can become entangled in materials such as nylon strings and the plastic from carrier bags, preventing them from feeding and eventually causing them to starve to death.

Solutions for pollution

There are two basic approaches dealing with pollution:

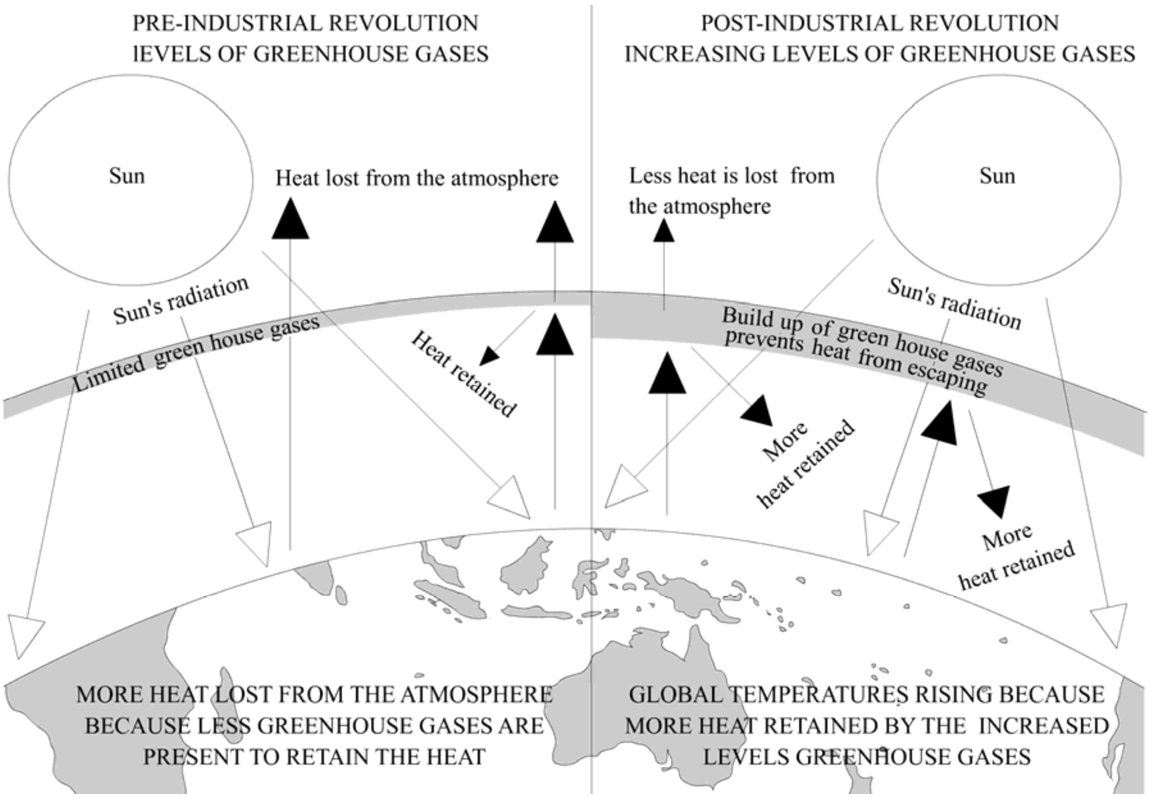
1. Prevent the pollution from reaching the environment – ***Input Pollution Control***.
    - Input pollution control slows the input of pollutants often achieved by switching to less harmful chemicals or processes.
    - Pollution can be prevented, or at least reduced, by the three "R's" of resource use: ***Reduce***, ***Re-use***, ***Recycle***.
    - Prevention should be emphasised because it works better and is cheaper.
2. Remove pollutants once they have already entered the environment **–** ***Output Pollution Control***.
    - Output pollution control involves cleaning up pollutants once they have been produced.
    - A good approach but is often a temporary remedy because, as long as population and consumption levels continue to grow, there may not be adequate pollution control technology.
    - Pollution clean-up sometimes removes a pollutant from one part of the environment only to pollute another part. E.g. we can collect rubbish, but it is then typically burnt – causing air pollution.
    - Once harmful concentrations of pollutants have entered the air, water and soil, it is usually prohibitively expensive to reduce the pollutant concentrations to acceptable levels.

There is no simple solution or definitive answer, but the best approach to minimising pollution is to prevent it right from the start:

Remember

– PREVENTION IS BETTER THAN A CURE -

The greenhouse effect & global warming



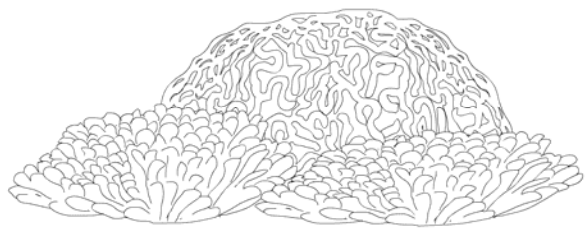
Since the industrial revolution, humans have released large quantities of gases such as carbon dioxide and methane into the atmosphere. These gases are called “greenhouse gases” because they trap the heat from the sun in the Earth’s atmosphere. Increasing levels of greenhouse gases in the atmosphere have lead to an increase in the global temperature – this is known as “Global Warming”.

Scientists warn that global warming will cause serious problems for humans and the Earth’s ecosystems. Some of the predicted impacts of global warming are:

- Increased frequency and strength of tropical storms and cyclones.
- Rise in sea level.
- Changes to rainfall patterns and subsequent impacts on crops and farming.
- Changes to the distribution of plants and animals.

Greenhouse gases are released during the burning of fossil fuels, such as coal, petrol, and gas. They are also released by many industries and by the burning of forests and other vegetation. Forests help reduce the amount of greenhouse gases in the atmosphere because trees use up carbon dioxide during the process of photosynthesis. Deforestation contributes to global warming because; (1) there are fewer trees to absorb carbon dioxide from the atmosphere and (2) burning waste vegetation causes more carbon dioxide to be released into the atmosphere.

Sea level rise & coral bleaching



Global warming is causing many negative impacts on the Earth. One such impact is a rise in sea level. Global warming is causing the sea to rise because: (1) water expands slightly as it warms, and (2) warmer temperatures are melting glaciers and other large areas of ice, such as the polar ice caps.

Sea levels will continue to rise as the earth's temperature increases through global warming. The rise in sea level will mean that many low-lying areas of land will become inundated by the ocean and low islands may disappear altogether. Some island nations in the Pacific are threatened by rising sea level.

Global warming is also causing the average temperature of the ocean to increase. This increase in ocean temperature is thought to be responsible for widespread coral bleaching that have been observed on many reefs around the world. Coral bleaching occurs when corals lose their zooxanthellae in response to high water temperature. The loss of zooxanthellae causes the corals to lose their colour and become very pale. Corals cannot survive very long without zooxanthellae and will eventually die.

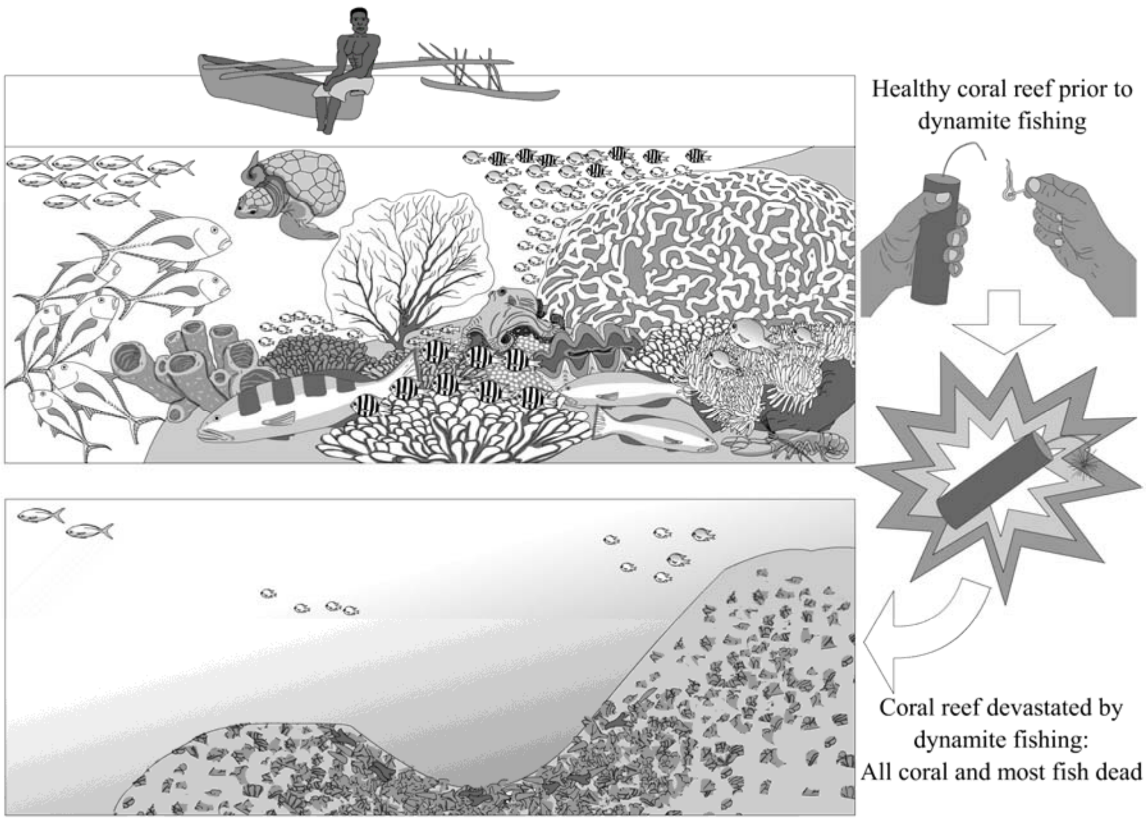
Coral bleaching happens when the water temperature is just a few degrees higher than the average maximum temperature usually experienced at a location. The longer the water temperature stays unusually warm, the more likely it is that corals will bleach and die. Coral bleaching has caused a serious loss of coral cover on reefs in many parts of the world. Repeated episodes of coral bleaching over a short time period are particularly serious to reef health because the reef does not have time to recover and grow new corals before the next bleaching episode occurs.

Harmful activities in the sea

There are many activities that occur in the sea that can damage coral reefs. Sadly, as the size of coastal populations and the demands they make upon marine resources increase, the intensity of these harmful activities will grow. This section outlines some of the harmful activities that occur in the sea, their effects, and ways to limit or prevent this.

Destructive fishing practices

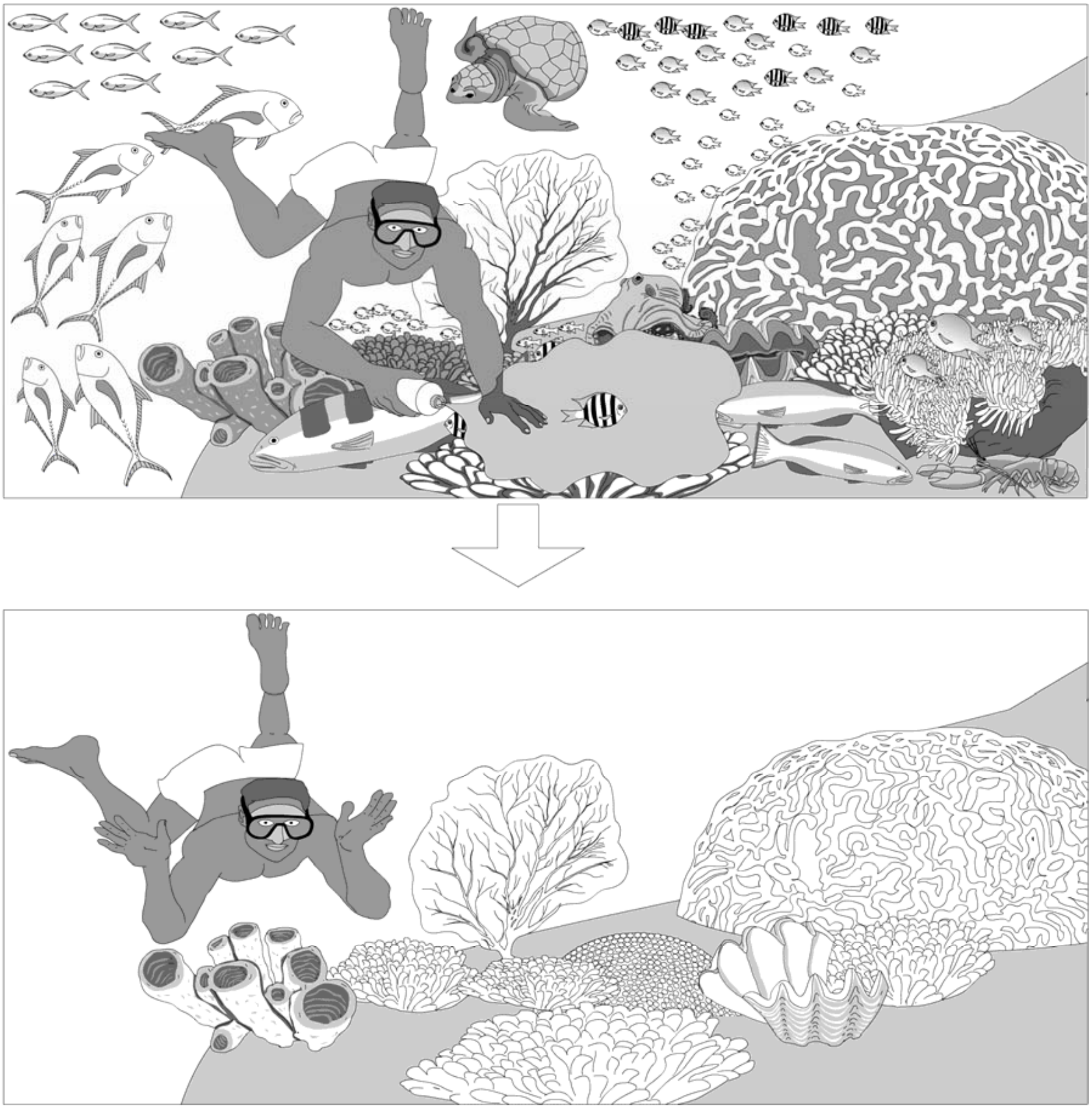
Dynamite and blast fishing



Dynamite kills many fish that are never collected. It is a very wasteful technique. Like poisons, dynamite kills small fish and other animals and plants that are needed in the food chain. Dynamite also destroys the reef structure, breaking corals apart and killing polyps. Reefs subjected to dynamite or blast fishing are usually reduced to rubble and these reefs no longer support the biodiversity usually found on coral reefs. Dynamite is also responsible for killing and maiming many of the men and children using it to catch fish.

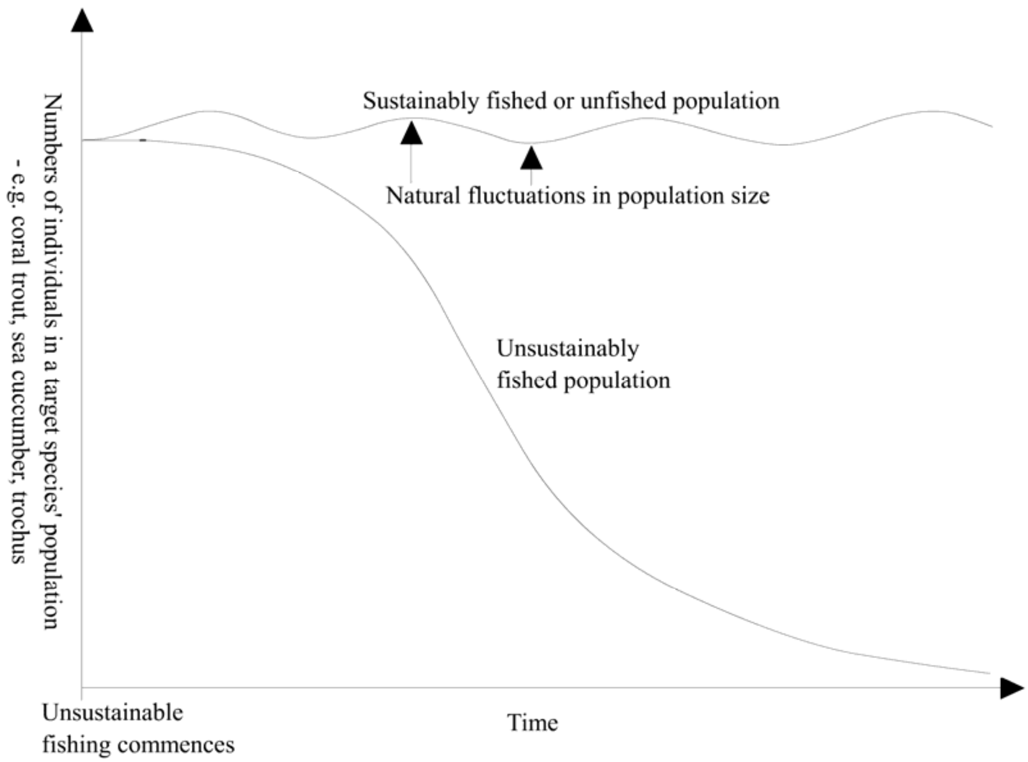
Dynamite should never be used to catch fish. There are many other sustainable ways to catch fish that do not destroy the reef ecosystem.

Cyanide, poison and poison root fishing



Many poisons such as cyanide, rotenone, poison (derris) root and bleach are used to catch fish on coral reefs. These poisons not only stun the fish targeted for collection, they also kill corals, small fish and other animals and plants. Cyanide is used for catching aquarium fish. Once these fish have been sold to many of them then die from the effects of the poison. This creates a high turnover of aquarium fish leading to greater a greater demand, and more areas of reef being subjected to cyanide fishing and being killed. Cyanide is a very dangerous poison which has killed many of the fishermen using it.

Overfishing



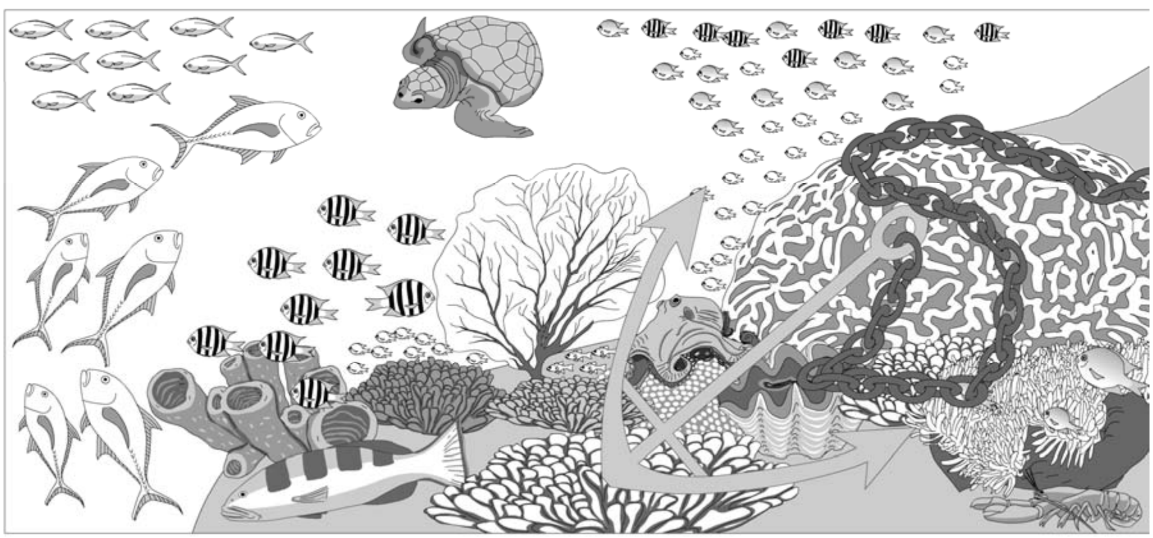
Overfishing occurs when an unsustainable quantity of fish is removed from a population. This leads to declines in the numbers of individuals in the populations of the species targeted. Severe overfishing can cause populations to become locally extinct. Overfishing also has associated problems: once a population of target species is overfished, either to extinction, or to such a degree that it is no longer financially viable to target this species, then fishing pressure turns to other species. In this fashion many species can be systematically overfished on a single reef as fishing targets the next most desirable species.

A good indication that a species is being overfishing on a reef is if it is becoming harder to catch as many of that species (fish, seacumbers, clams, etc…) as before – this shows that there are less of them now than previously. Overfishing of species can be prevented by spreading fishing efforts over many reefs, spreading the cost of fishing over as many species as possible, ceasing to catch fish on reefs that appear to have less fish than before, and ceasing to catch species that are obviously not as numerous as previously. This will prevent the most easily accessible reefs (the reefs that usually suffer the highest fishing pressures), and the most easily caught or most preferred species (the ones that get overfished most quickly as they are targeted more), from being overexploited, and allows those already overexploited reefs and species to recover.

Coral mining

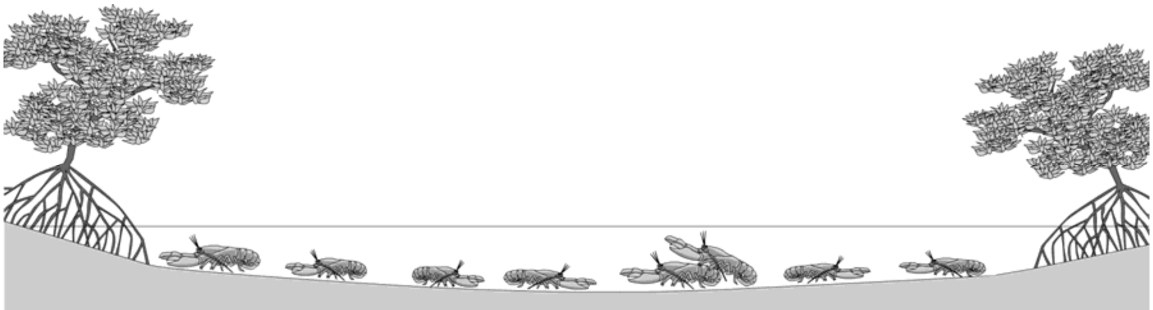
The removal of coral materials for buildings and road construction can be devastating for coral reefs. Coral mining removes the living habitat upon which many species of plants and animals depend for their survival.

Anchor, boat and diver damage



Any human activity on or around coral reefs can lead to needless damage of reefs. Anchors dropped on reefs with no regard to where they land break and kill corals. Boats running aground will kill the areas of reef that they hit. Thoughtless divers can crash into the reef damaging the very beauty they came to witness. Although each incident may only damage small areas and seems negligible, recurrent damage over time may not be met by the reef's ability to recover.

Mariculture



The farming of marine plants and animals, which includes giant clams, fish, conch, seaweed and shrimp is known as ***mariculture***. Mariculture is becoming more popular in the tropics, often in response to the loss of wild stocks. While providing employment and reducing pressure on over-exploited stocks, it can also have negative impacts on the reef. In many areas entire mangrove forests have been removed to make way for shallow ponds for these farms, eliminating juvenile fish nurseries, habitat for marine birds and animals, and destabilising the sediment that was retained by the mangroves' roots. In many places, these shallow ponds last for only a short time before they are no longer useful for mariculture. When this occurs, another area of mangrove has to be cleared for new ponds, and so the mangrove forest becomes more and more depleted. Often, the chemical content of the soil in the now disused areas cleared for mariculture is such that they can no longer be recolonised by mangrove plants.

Whilst mariculture has the potential to relieve harvesting of wild populations, many of the organisms cannot be bred in captivity due to the complicated requirements of many larval stages of fish and invertebrates, so juveniles or late larval stages of these species have to be removed from wild populations and then raised in captivity. Once all stages of target species' life cycles can be raised in captivity, and if mangrove areas are not cleared for ponds, then mariculture may truly relieve pressure on wild populations.

Inappropriate use of fishing equipment

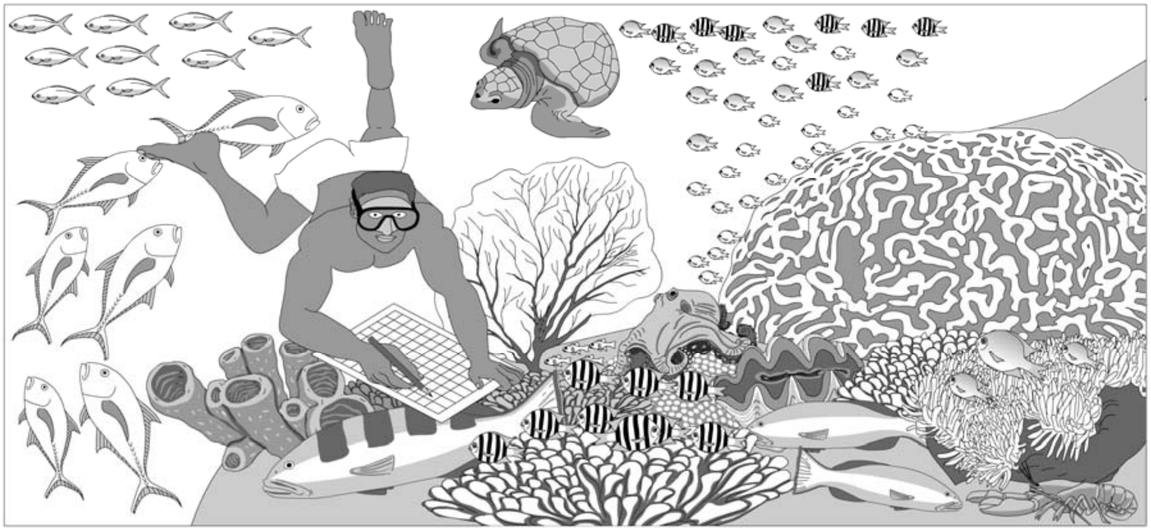
There are some fishing techniques that are not intrinsically destructive, but if used carelessly can cause needless damage to reefs.

> ***Traps*** can damage corals if not placed carefully. Corals should never be broken off in order to be put over traps to camouflage them traps, or put inside the traps to weigh them down.
>
> ***Nets*** can be destructive if not handled properly. Dragging nets over reefs can damage corals. Nets can catch too many fish from a single location, damaging the population structure of the species in question (see overfishing above). Nets can also catch and kill a lot of unwanted fish.
>
> ***Targeting spawning aggregations of fish*** is a method that should be used with extreme caution. Spawning aggregations are formed when many fish of the same species migrate to a particular location to reproduce. It is very easy to catch unsustainable quantities of fish at spawning aggregations. The targeting of spawning aggregations of reef fish throughout the Indo-Pacific and Caribbean has lead to enormous declines in populations of target species.
>
> ***Fishing whilst night diving*** is also a technique that can lead to the removal of unsustainable quantities of fish from populations, because it is too easy to catch fish especially with the widespread use of electric torches.

Coral reefs' abilities to recover

Both natural disasters and human activities threaten coral reefs worldwide. Whilst natural disasters such as hurricanes and cyclones have always impacted coral reefs, man's activities are reducing coral reefs' abilities to recover from these natural phenomena. Coral reefs were capable of recovering from the natural impacts they suffered. Natural impacts are usually ***acute***, occurring as "one-off" events of high intensity lasting a short period of time. However, man's impacts on reefs can be ***chronic***, occurring constantly at varying intensities over prolonged periods of time. Whilst coral reefs are able to recover from acute episodes, they are not as well equipped to deal with chronic impacts. A reef already subject to chronic stresses (induced by human activity) can suffer greatly when then hit by a natural impact such as a cyclone. Such chronically stressed reefs will not only suffer more than unstressed reefs from these natural impacts, but they will also be less able to recover and may not even recover at all.

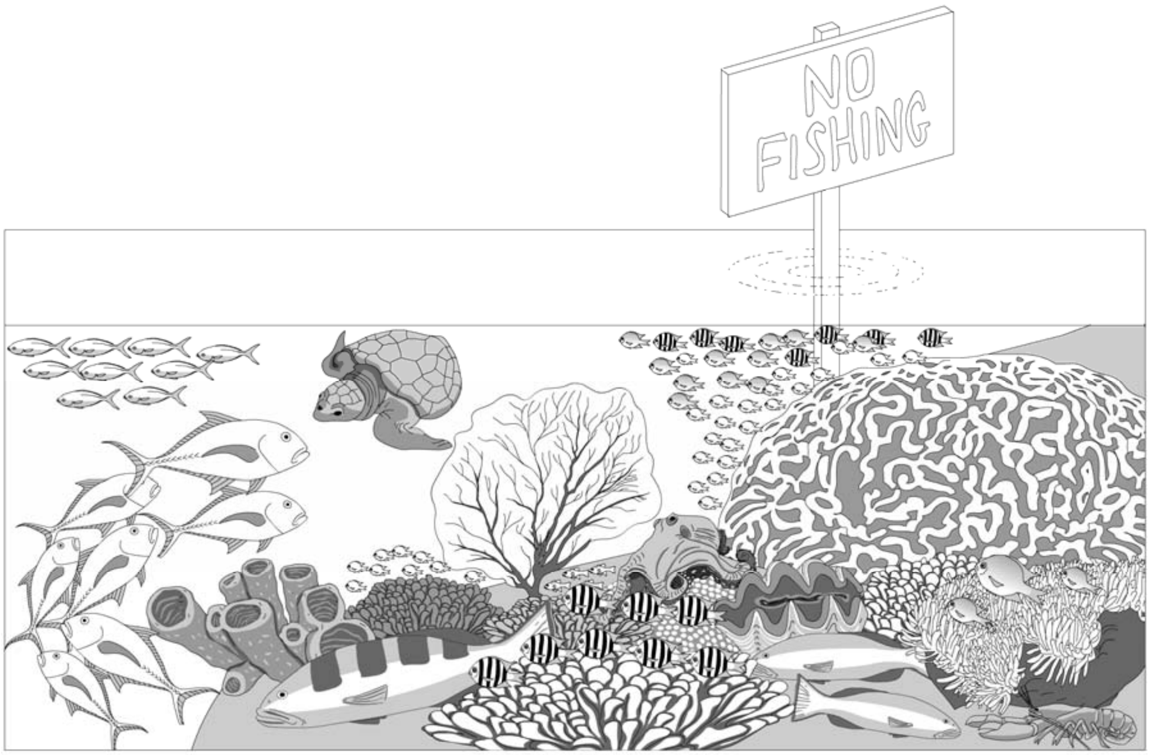
Monitoring



Monitoring is the process by which a record is kept of an item of interest over a period of time. In this way monitoring allows us to see if there has been a change over time in the item of interest. For example, if you wished to know whether the numbers of sea cucumbers on a reef was declining, then you would record the numbers of sea cucumbers on that reef over successive time intervals. The data collected would enable you to say that sea cucumber populations were – (1) declining, (2) stable or (3) actually growing. Once a pattern has been established (i.e. that sea cucumber numbers are declining) then it is possible to make management recommendations. In this case, the management recommendation might be to reduce catches of sea cucumber until the populations have appeared to recover.

Monitoring also enables people to be held accountable for actions they make that damage the environment. One of the problems is that habitat degradation or damage to the environment happens at a slow and unperceivable rate and can go unnoticed until it is too late. If a reef monitoring program was in place before a planned terrestrial activity such as large-scale clearing of bush for a plantation, then it is possible to state that the activities of the company clearing the bush has accompanied unprecedented declines in coral cover, fish abundance and increases in algae and sediment. It is very hard to assign blame definitively, as this could all be coincidence or due to some other process but such monitoring data can be very compelling.

Marine protected areas



The concept of protected areas is not new. Traditionally, resource use in certain terrestrial and coastal marine areas was prohibited, both permanently and over specified periods of time. The idea of protecting certain areas has spread in the last one hundred years or so, since 1872, when what is considered the world's first national park was established in Yellowstone, USA. It is now generally accepted that the most effective way to conserve any ecosystem is to set aside an area where all potentially detrimental activities to that ecosystem are prohibited. Accordingly, ***Marine Protected Areas*** (MPA's) have developed throughout the world so as to help conserve marine ecosystems. An MPA is:

- An area of sea secure from unrestricted use of resources
- An area of sea specifically managed to meet nature conservation objectives

Marine parks, marine reserves, marine sanctuaries, and marine wilderness areas are all forms of MPA. MPA's are important because they:

- Help maintain healthy populations of many different kinds of marine animals
- Help maintain large populations and large adult individuals

- Become a source of eggs and young which can spread to other areas
- Become sources of adults that support other areas through natural movement of fish

The goal of MPA's is to protect a sufficiently large region of the ocean so that the representative ecosystems and their associated biodiversity can survive. The restrictions in place differ from one MPA to another, depending on the specific management goals of each MPA. For example, some MPA's are ***no take reserves*** where all extractive activities are banned, whilst other MPA's may allow restricted harvesting of certain species, during a specified time of the year.

MPA's established on coral reefs are believed to benefit more than just the area of coral reef that falls within the MPA's. Not only will the fish stocks, coral cover and overall health of the reef area within the MPA improve over time, but this improvement will also be seen in the areas of reef outside the MPA. This is largely because of the ***bipartite*** life cycle of many marine organisms. The MPA's will act as sources of eggs and larvae of animals that have ***pelagic larval phases***. These eggs and larvae will develop in the ***pelagic zone*** and eventually settle on reefs, growing into juveniles and then adults. Thus, nearby unprotected reefs will be supplied with juvenile fish, corals, sea cucumbers and other harvestable organisms that came from the MPA. Whilst supplying juvenile fish to unprotected area, MPA's are also believed to be a potential supply of adult fish. Over time, as the fish sticks within the MPA recover there will be so many fish that some adults will have to move away from that area so as to avoid the problems of overcrowding. This creates a ***spill-over*** of adults into unprotected areas outside the MPA. Spill-over will be limited by the MPA's degree of separation from other reefs, and how well certain species of fish can swim.

Compliance with MPA's

MPA's are successful only if they have appropriate management. This requires an understanding of the regulations need to be established and ensuring that people comply with these regulations. If nobody obeys the rules, then the establishment of MPA's is worthless. It is therefore important to find the best way to get people to comply. One obvious solution is to police the MPA and punish anyone caught breaking the rules. Punishment can be in the form of fining individuals or confiscating the equipment they used whilst poaching (e.g. boats or fishing equipment). Policing may be effective in the short-term, but it is expensive, and does not encourage a co-operative relationship between the MPA managers and the public.

The most effective way to ensure compliance with MPA regulations is to make people want to comply, not because they will be punished if they break the rules, but because they know they will benefit from a successful MPA. This can be achieved by involving the public with every stage of the MPA development process, and making the public aware of the benefits that a healthy MPA will have. This will eventually nurture a public attitude embracing the MPA as their own, and not regarding it as an imposition placed upon them by an uncaring regulatory body – an attitude that might develop under a heavy-handed policing approach. Public awareness and education is key to the success of MPA’s. For example, a common misconception is that establishing an MPA will reduce the number if fish that people will be able to catch. It is important to let the public know that by safe-guarding an area that supplies eggs and larvae, and adult spill-over, MPA’s have the potential to increase the amount of fish people can catch, especially over time. Unrestricting fishing may initially land large catches of fish, but will exhaust these stocks in a few years. Establishing MPA’s helps to create more sustainable fisheries over the long term. The goal of most MPA’s is to make resource use more sustainable.

Locally managed marine areas

Locally managed marine areas (LMMA’s) are a form of MPA. LMMA’s embrace the concept of public participation in the MPA process. Independently, or through consultation, it is the resource owners and users themselves who designate areas to be protected and managed. They decide what regulations to put in place and how to enforce them. The community involvement in LMMA’s makes compliance more widespread and the goals of the protected area are more likely to be successful.

The LMMA Network was launched in October 2000. Members in the LMMA Network share knowledge, skills, resources and information with one another in order to learn collectively how to improve marine management activities to increase positive conservation impact.

Glossary of terms

Acute – occurring as a "one-off" incident over a short period of time, as compared to **chronic**
Agnatha – fish without hinged jaws
Algae – plants that grow in water. Can be planktonic – **phytoplankton** – or attaches to subtstratum
Aristotle's lantern – the five sided feeding apparatus of a sea urchin
Ascidians – "sea squirts" – two chambered marine invertebrate
Asexual reproduction – reproducing without fertilising an egg with sperm. Opposite to **sexual reproduction**
Atoll – ring of coral reef formed by sea level changes around a volcanic island
Benthic – pertaining to marine organisms attached to the substratum
Biodegradable – will decompose naturally
Biodiversity – the richness and diversity of organisms
Bio-erosion – erosion caused by animals or plants
Biological control – the influence of one organism that limits the growth or reproduction of another organism.
Bipartite life cycle – having two parts to the life cycle. For marine animals, **bipartite** describes life as juveniles and adults on coral reefs or other habitats, and the **pelagic larval phase**
Bivalves – the two shelled **molluscs** such as clams and oysters
Brooders – animals that take care of their young such during some stage of their offspring's development
Bryozoans – a type of marine invertebrate usually found living in colonies attached to some form of substratum
Buffer zones – protective areas of natural vegetation left around water courses in order to limit the run-off of sediment
Calcium carbonate - limestone
Carbohydrate – the food produced by photosynthesis
Cartilaginous – made of cartilage
Catabolism – the process that breaks down proteins
Cephalopods – a type of mollusc such as octopi, squid and cuttlefish
Cetaceans – marine mammals such as dolphins and whales
Chitons – single-shelled marine molluscs that attach to hard substratum
Chondrichthyes – fish with **cartilaginous** skeletons such as sharks and rays
Chronic – occurring over prolonged periods of time, as opposed to **acute**
Ciguatera – the food poisoning caused by eating seafood affected by **ciguatoxin**
Cilia – the microscopic hairs that can be found on the surface of some cells
Ciliary action – the movement of **cilia**
Cnidaria – the group of animals containing jellyfish, corals, and anemones
Coelenterates – synonymous with **cnidaria**
Cold-blooded – unable to regulate body temperature without external influences – e.g. lying in the sun
Colony – a number of individuals of the same species living together
Coral – a type of **cnidarian** which secretes a calcium carbonate skeleton, and forms reefs
Coral bleaching – the loss of **photosynthetic pigment** from a coral's tissues, usually in response to prolonged exposure to increased temperatures involving the loss of **zooxanthellae** from the **polps'** tissues
Coralline red algae – a benthic algae that forms hard structures
Corallites – the distinctive individual skeleton of each **polyp**
Crustaceans – the group of **invertebrates** including crabs, lobsters and prawns
Decompose – the break down of material
Deforestation – the removal of areas of forest
Delta – the network of streams, rivers and estuaries that branch out in a tree-like fashion in the areas where rivers meet the sea
Diatoms – single-celled algae that have a cell wall made of silicon
Discontinuous – not linked to one another
Echinoderms – the group of **invertebrates** including starfish, sea urchins and sea cucumbers
Ecosystem – ecosystems are composed of distinctive assemblages of interacting organisms. Coral reefs, rainforests, mangroves, and seagrass beds are all examples of ecosystems
Ectodermis – an organism's external layer of cells
Ecto-parasites – the parasites that attach to animals' skins
Erosion – the wearing down of rock
Excreta – waste food that has been processed through animals. Synonymous with faeces
Exhalent pores – the holes through which water leaves
Extinction – the loss of a species. Can occur on a **globally** – all individuals of that species have died on the planet – or **locally** – all individuals of that species within a certain area have died
Fertilisation – the fusion of two **gametes**, in the case of animals this involves eggs and sperm
Flukes – the tail of marine mammals
Gamete – eggs and sperm are both gametes
Gastropods – the group of molluscs that include snails and cone shells
Genetic – coded for by **genes** – the groups of **DNA** that can be found in the nucleus of all cells of all living organisms
Gills – the apparatus used by fish for gas exchange in the water – oxygen is absorbed into the bloodstream and carbon dioxide is expelled out
Global warming – the process whereby the Earth's temperature is rising, generally attributable to the **greenhouse effect**
Gnathostomata – fish with hinged jaws, as opposed to **agnatha**
Greenhouse effect – the trapping of heat by **greenhouse** gases such as carbon dioxide and methane in the atmosphere. These **greenhouse** gases have been produced by man's industrial activities and have lead to **global warming**
Habitat – the characteristic environment where an organism lives
Herbivorous – pertains to an animal that eats plants
Hermaphroditism – pertains to an animal that is both male and female during its life time, either by changing sex or by being both sexes at the same time
Inhalant pores – the holes through which water enters
Input pollution control – the prevention of **pollution** by stopping the production of **pollutants** in the first place, as compared to **output pollution control**
Intertidal zone – the area of coast that is exposed at low tide and underwater at high tide
Invertebrate – an animal with no backbone, as opposed to **vertebrate**
Larvae – the developmental stages of many **invertebrates**
Live reef food fish trade – the trade in live fish for food, involves the transportation of live fish in boats or planes to consumer nations in Hong Kong and Southern China

Locally managed marine areas – a form of **marine protected area** established and run by local communities
Mammal – the group of **warm-blooded vertebrates** that includes humans, dogs, whales, dolphins and dugongs
Mangrove – describes both single trees and forests of trees that are able to withstand their roots being submerged in seawater
Mantle – the fleshy part of molluscs that protrudes from their shells, or enclosed by their tentacles in the case of some **cephalopods**
Mariculture – the farming of marine animals and plants
Marine protected areas – areas of sea (and sometimes coastline) that is protected from unlimited human activities
Mesenteries – the internal parts of coelenterates
Mesoglea – the gelatinous middle layer of tissue found in **cnidaria**
Metamorphose – changing of body shape and structure
Mollusc – the group of **invertebrates** including snails, nudibranchs, squid, octopus and cuttlefish
Monitoring – keeping of a continuous record over time
Mucous – the slimy protective secretions of many animals
Nematocysts – the stinging cells of **cnidaria**
Neurotoxin – a poison that damages the functions of the nervous system
Nitrogenous – containing nitrogen
Nudibranch – a shell-less marine mollusc
Nutrients – the chemicals required by plants
Organism – any living being
Osmotic shock – the **physiological** stress caused by cell membranes being exposed to liquids of abnormal salinities
Osteichthyes – the group of fish with bony skeletons
Out-compete – the process whereby the survival and growth of one **organism** limits the survival and growth of another
Output pollution control – the measures taken to reduce the effects of **pollution** already in the environments, as opposed to **input pollution control**
Overexploit – taking too much of a resource
Pelagic spawning – **spawning** by releasing eggs and sperm into the water
Pelagic zone – the open ocean
Pelagic larval phase – the developmental stage of **larvae** in the **pelagic zone**
Pelletised – formed into pellets
Penta-radiate symmetry – radial symmetry showing five repetitions
Pharynx – throat
Photosynthesis – the harnessing of energy from the sun to produce **carbohydrate**
Physiological – pertaining to the internal workings of **organisms**
Phytoplankton – **planktonic algae**
Planktivores – animals that eat **planktonic organisms**
Planktonic – organisms that passively drift in water
Planula larvae – the free swimming **larval stage** of corals
Plume – the slick caused by the discharge of something into the water
Polar Ice Caps – massive bodies of water frozen into huge land masses at the North and South Pole
Pollutant – material or energy causing **pollution**
Pollution – any
Polyp – the coral animal
Porifera - sponges
Predators – animals that eat other animals
Primary productivity – the same as **photosynthesis**
Protandrous – changing sex from male to female
Protogynous – changing sex from female to male
Radial symmetry – having an appearance that is similar when turned on an axis
Radula – the abrasive tongue of some **molluscs**
Reef – any hard structure in the sea. Can be formed by, rocks, **corals**, and even **coralline algae**
Replenishable – will grow back
Reproduction – the process whereby an **organism** will create a daughter **organism**
Reptile - the group of **cold-blooded** vertebrates that include snakes, turtles and crocodiles
Resource – natural materials or minerals that are used by man
Respiration – the conversion of **carbohydrate** and oxygen into energy
Rhizomes – similar to roots
SCUBA – stands for "self-contained underwater breathing apparatus"
Sea level rise – the increase in the height of the sea relative to the land
Seagrass – the only marine flowering plant that forms meadows in shallow seas
Seamounts – steep upward projections of reef from **deep** sea floors
Sedimentation – the process whereby soils, and sediment from the land end up in rivers, lakes and seas
Sessile – attached to the **subtratum**
Sexual parasitism – rare form of **reproduction** in fish whereby the male is permanently attached, and fused to the female
Sexual reproduction – **reproduction** involving the fusion of two **gametes**
Spawning – describes many forms or aquatic **reproduction**
Spawning aggregations – temporary aggregations which have migrated for the specific purpose of **spawning**
Spawning rush – the upward rush by the male and female fish that precedes **gamete** release during **pelagic spawning**
Spicules – elements of skeletal structure in sponges
Spill-over – the movement of adult fish from marine **protected areas** into unprotected areas
Substratum – the surface of the sea floor, synonymous with **substrate**
Subtidal zone – the area of sea that is permanently covered in water regardless of the state of the tide, as compared with the **intertidal zone**
Sustainability – pertains to the use of natural resources in a fashion that will allow their continual replenishment
Symbiotic – co-dependent relationship, e.g. between the coral **polyp** and **zooxanthellae**
Synthetic – man-made
Taxonomist – a scientist who divides animals and plants into different groups
Tube feet – tentacle-like structures found on the outside of many **echinoderms**, used in feeding, adhesion and aggression
Vertebrate – the group of animals that have backbones
Warm-blooded – being able to regulate body temperature **physiologically**
Water vascular system – the internal system of **echinoderms** that controls their **tube feet**
Whaling – the capture and killing of whales
Zooplankton – aquatic animals that drift passively in the water
Zooxanthellae – the single-celled **algae** that live **symbiotically** within **polyps'** tissues

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