SPREP

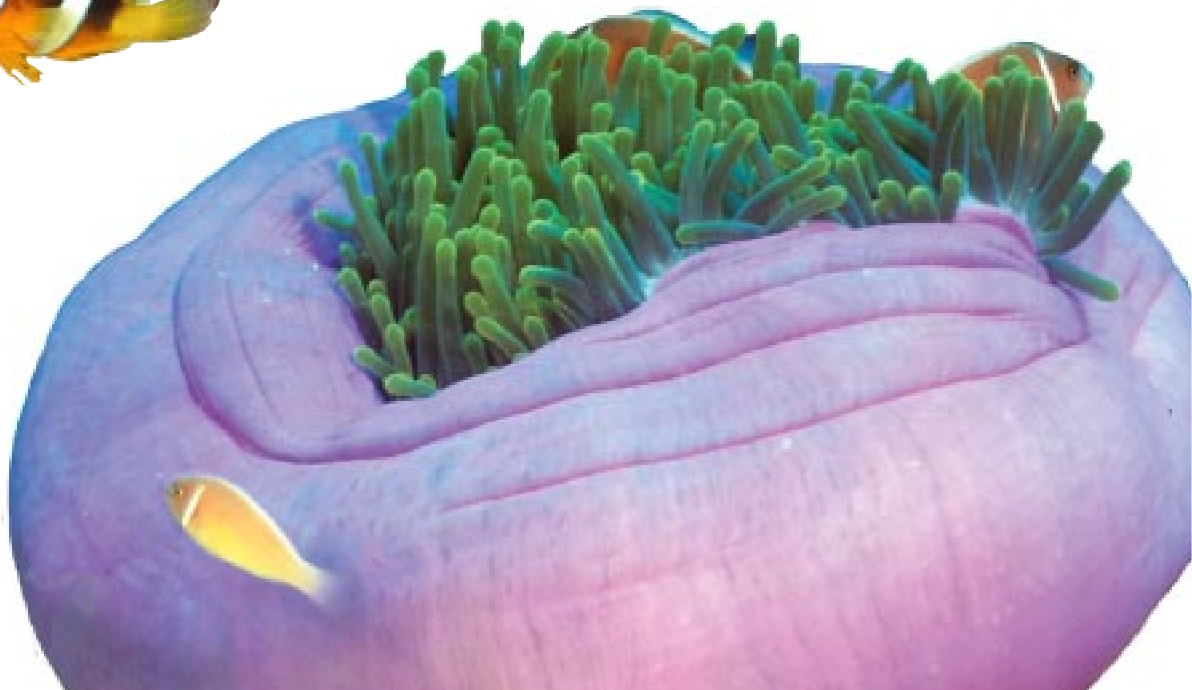
from mangroves to coral reefs

sea life and marine environments in Pacific islands

Michael King

ICRAN
International Coral Reef Action Network

CANADA - SOUTH PACIFIC OCEAN DEVELOPMENT
C-SPOD



South Pacific Regional Environment Programme

SPREP Cataloguing-in-Publication
King, Michael
From mangroves to coral reefs;
sea life and marine environments in Pacific islands
by Michael King
Apia, Samoa: SPREP 2004

This handbook was commissioned by the South Pacific Regional Environment Programme
with funding from the
Canada South Pacific Ocean Development Program (C-SPODP)
and the
UN Foundation through the International Coral Reef Action Network (ICRAN)

SPREP
PO Box 240
Apia, Samoa
Phone (685) 21929 Fax (685) 20231
Email: sprep@sprep.org.ws
Web site: www.sprep.org.ws

From mangroves to coral reefs

sea life and marine environments in Pacific islands

Acknowledgements

This handbook was produced with funding from Canada's South Pacific Ocean Development Programme (C-SPODP) and the UN Foundation – UNEP International Coral Reef Action Network (ICRAN).

The project was initiated by Mary Power, Coastal Management Officer, and Seema Deo, Education Officer, of the South Pacific Regional Environment Programme (SPREP).

Thanks are due to Mary Power for comments on the manuscript and to Paul Stapleton of SPREP for advice on publication.

From mangroves to coral reefs

Sea life and marine environments in Pacific islands

1. Introduction

A community of living things, along with its surroundings, is referred to as an ecosystem. An ecosystem often takes its name from the most common, or most obvious, thing present. The parrotfish shown in Figure 1.1, for example, is said to be part of the coral reef ecosystem.

This handbook is about marine and coastal ecosystems in the Pacific islands region. The 22 islands named in Table 1.1 and shown in Figure 1.2 are Member countries and territories of the South Pacific Regional Environment Programme (SPREP) and are spread out over the world's biggest ocean. These island countries are characterised by having small areas of land, large areas of sea and populations that, in many cases, are increasing (Table 1.1).

Initial sections of this handbook describe some of the ecosystems common in the region – wetlands, mangrove forests, sandy shores, seagrass meadows, lagoons and, of course, coral reefs.

Subsequent sections describe some of the living things that are components of these ecosystems. A profile of a high island, showing the juxtaposition of some of these ecosystems, is given in Figure 1.1.

Many of the living and non-living components of these ecosystems are exploited by people. Wetlands are drained and filled in for housing, mangroves are cut down for firewood, sand is mined for making cement, and coral blocks are used for buildings. And, of course, a wide range of marine species is used as food.

Traditionally, seafood has been the most important source of protein in Pacific islands. Seafood consumption is highest in low-lying islands and coral atolls where soils are too poor to support agriculture. In Kiribati, for example, seafood consumption is 150 kg per person per year (compared with a world average of about 12 kg per person). Even in high islands where agriculture is well developed, seafood consumption often approaches 50 kg per person per year.

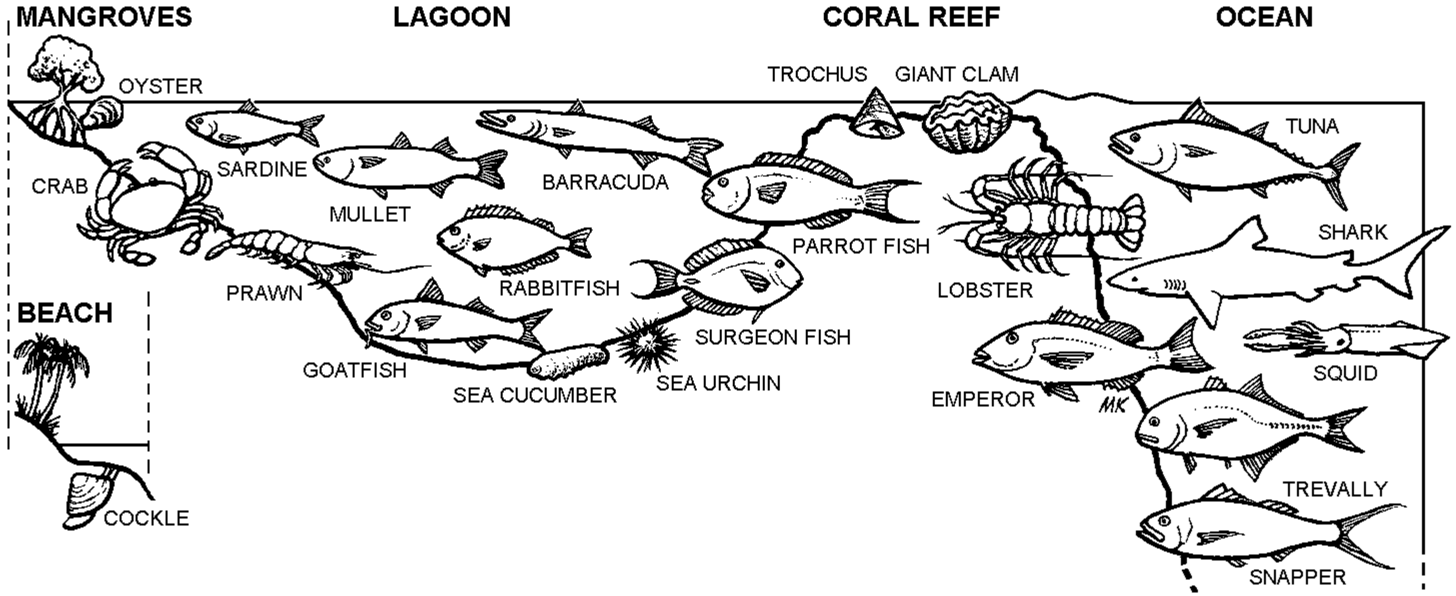


Figure 1.1: A profile of the coast of a high island showing the open ocean, barrier coral reef, lagoon and either a mangrove forest (above) or a sandy beach (below). The distribution of some common marine species is shown.

However, catches of the most accessible seafood - the fish, seaweed and shellfish of the lagoons and reefs - have been declining in some island countries over many years.

Reasons for the decline in inshore catches include overexploitation, environmental degradation and the use of overly efficient and destructive fishing methods (including the use of explosives and poisons).

Growth in population sizes will continue to place pressure on coastal ecosystems and their resources. And as demands for seafood species increase, the ability of the marine environment to sustain them is likely to decrease. The coast is in increasing demand for housing and development. And the sea that supports coastal ecosystems is being polluted by silt, chemicals and waste from towns, forestry, agriculture and industry.

In the past, people in local communities were low in number and were mindful of customary methods of conserving the coastal environment and seafood stocks. Traditional management methods, however, have been eroded with increasing populations and a trend towards money-based economies and commercial fishing.

The freedom to use the marine environment and exploit resources without control is now likely to be at the expense of someone else's freedom to do the same thing. Some of these freedoms must be sacrificed to allow the continuing use of the marine environment and its resources by present and future generations.

The use of coastal ecosystems requires sensible controls and regulations to avoid damage that is hard, or even impossible, to reverse. The renewability of natural resources depends on our ability to see that too many animals and plants are not harvested, and that the environment on which they depend does not deteriorate.

Local authorities and organisations in Pacific islands have identified the most important threats to their local marine environment in a directory produced by SPREP (Coastal Management Profile, 1999). These threats are summarised and discussed in this handbook. For the convenience of teachers and students using this handbook, a glossary of terms and sample assignments are included in the final sections.

Table 1.1: Land areas (in km^2), sea areas (Exclusive Economic Zones in km^2) and populations of Pacific island countries.

Country/State/Territory	Land area	EEZ area	Population
American Samoa	197	390 000	57 000
Cook Islands	180	1830 000	18 100
Fiji	18 376	1290 000	768 700
French Polynesia	3521	5030 000	221 300
Guam	549	218 000	150 000
Kiribati	726	3550 000	80 400
Marshall Islands	720	2131 000	56 500
Micronesia, Federated States of	702	2978 000	125 100
Nauru	21	320 000	10 400
New Caledonia	19103	1740 000	186 800
Niue	258	390 000	2200
Northern Marianas	475	1823 000	71 800
Palau	500	629 000	16 900
Papua New Guinea	461 690	3120 000	4173 200
Pitcairn	5	800 000	100
Samoa	2934	120 000	163 900
Solomon Islands	29 785	1340 000	375 000
Tokelau	12	290 000	1600
Tonga	696	700 000	98 900
Tuvalu	26	900 000	9900
Vanuatu	12 189	680 000	168 300
Wallis & Futuna	124	300 000	14 700
TOTALS	552 789	30 569 000	6 770 800

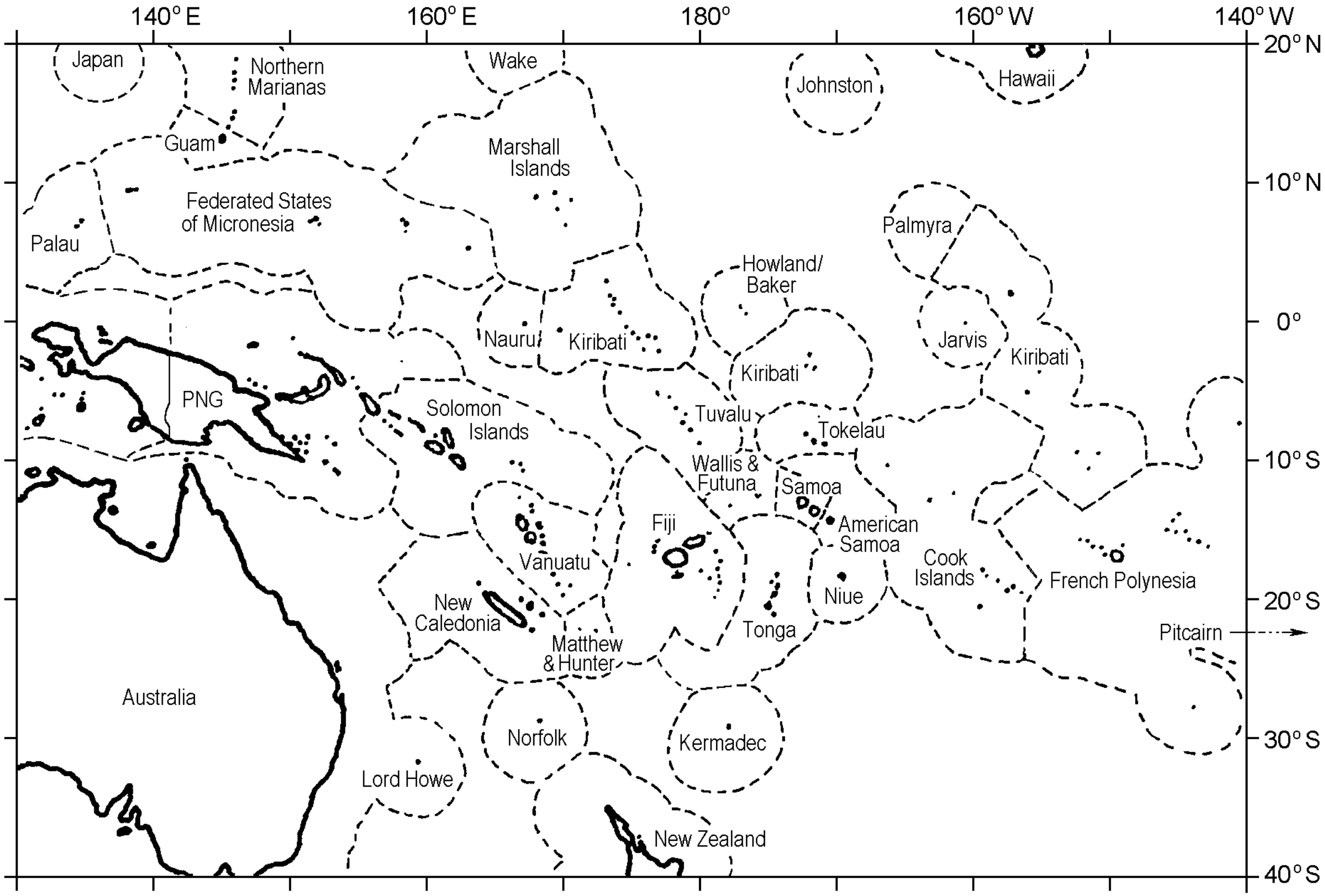


Figure 1.2: The Pacific island region showing the 22 island states of the central and western Pacific generally referred to as Pacific Island Countries or PICs (see Table 1.1). Other countries are included for geographic reference. Exclusive Economic Zones (EEZs) are indicated by broken lines (see Section 10).

2. Coastal wetlands - estuaries and mangroves

Coastal wetlands are places where plant communities are living in permanently wet areas. These are marshy areas or swamps that have generally not been highly regarded. In the past it has been common to use such areas as rubbish dumps or to fill them in for coastal development.

However, wetlands are now appreciated as important ecosystems that support many different kinds of plants and animals. For many aquatic animals, wetlands are important nursery areas – places where juveniles grow up before moving into rivers or out to sea.

In high islands, clouds gather around the mountains and produce heavy rain that washes across the land into valleys and rivers. Rain builds up underground reserves of water that feed springs and wetlands. And where the water enters rivers, these meet the sea in particular wetland areas called estuaries.

Estuaries – where rivers meet the sea

As rainwater washes across the land it picks up minerals and organic material. This material flows down rivers to make estuaries, at the mouths of rivers, some of the most productive of all marine ecosystems.

Rivers often widen or branch into several outlets (or a delta) as they approach the sea. This widening causes the flow of water to slow down and, as it slows down, it release its load of lighter particles. These particles settle out of the water to form large banks of silt and mud flats at the mouths of the rivers.

Marine plants take hold in these rich deposits and provide shelter and food for a large range of herbivores – animals that feed on plant material. Worms, clams, and many other smaller creatures feed on the organic material, and these in turn provide food for larger animals including fish.

Estuaries, with their abundance of aquatic life, are particularly common in the high islands of Melanesia such as Papua New Guinea, New Caledonia and Fiji (see Figure 1.2).

Mangroves – coastal forests

Of the many thousands of different species of trees on earth there are only about eighty that can exist with their roots in salty water. These specialised, but often unrelated, trees that have invaded the edge of the sea are collectively known as mangroves (Figure 2.1).

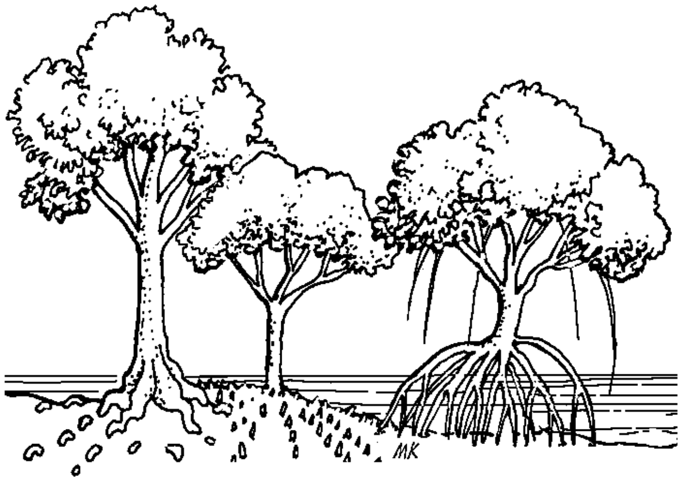


Figure 2.1: Mangroves - examples shown are (from left) the orange mangrove, *Bruguiera,* with knee roots, the white mangrove, *Avicennia,* with cable roots, and, the red mangrove, *Rhizophora,* with stilt roots.

Mangroves occur across the Pacific region but there are more different species in the west than in the east - there are 45 different species of mangroves in Papua New Guinea, 33 in the Solomon Islands and only 7 in Fiji (see species diversity in Section 6).

Most mangroves cannot survive in water quite as salty as the sea. They usually grow in the brackish water of estuaries or on coasts where the seawater is diluted by freshwater soaks or by run-off from the land.

Mangroves have several special adaptations to handle life at the sea's edge. As the trees grow in silty waterlogged soils many species have evolved exposed (or aerial) root systems that absorb oxygen as well as support the tree. The orange mangrove has knee roots that stick up above the silt. The white mangrove has cable roots that extend over a large surface area and send up small peg-like roots or pneumatophores. The red mangrove has long prop roots that grow down from the trunk.

Mangroves provide shelter for many marine creatures and produce large amounts of organic matter used as food. Through their root systems, mangroves take up nutrients that are dissolved in water running off the land. Parts of the mangrove, such as fallen leaves, rot away to form detritus and their contribution to marine food chains is considerable – it has been estimated that over one tonne of mangrove leaves may be produced each year by one hectare of mangrove trees.

The decaying leaves and detritus are used as food by crabs, shrimps and some fish. The fish families most common in mangroves include gobies, gudgeons, silver biddies, sardines, snappers, slip-mouths, puffers and mullets. The juveniles of some marine species such as prawns use mangroves as nursery areas in which to grow. Other species come into mangrove areas to breed, and many large fish live in or visit the mangroves to feed on smaller creatures (Figure 2.2).

Fish that visit mangrove areas to feed before moving back to other ecosystems are eaten by their own predators - this is an important mechanism in which the large amount of food in mangrove areas is made available to other less productive ecosystems.

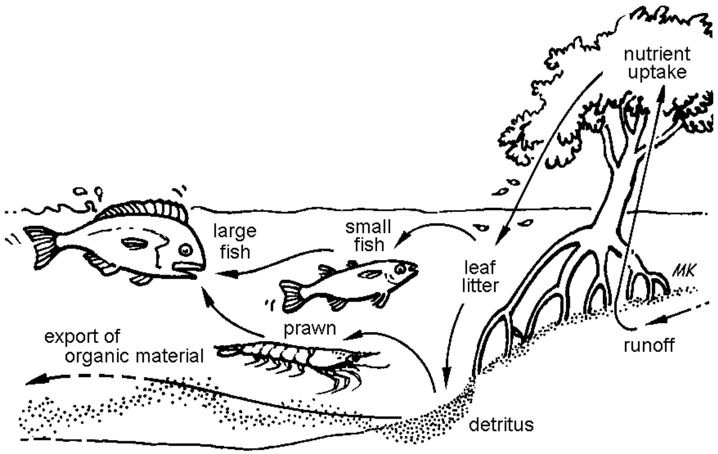


Figure 2.2: Mangroves take up nutrients dissolved in water running off the land. Leaves from mangroves are used as food directly or rot away to form detritus.

Mangrove areas also provide shelter and food for many terrestrial species. Many birds, including large hawks and eagles, are permanent residents of mangrove forests. Fruit bats or flying foxes, that move out to feed on fruit trees by day, often return to mangrove areas at night to roost in large colonies.

Mangroves are also important in protecting and building up shorelines. The exposed roots of mangroves cause currents to slow down and release some of their load of suspended material. The trapped particles and sediments gradually build up and extend shorelines. As the mangrove front slowly advances towards the sea, the newly formed land behind the front fills up with other tropical plants.

However, in many Pacific islands mangrove areas are still used as rubbish dumps or the trees are cut down and the land filled in for housing and other development.

Some coastal road construction which interrupts the mixing of fresh and salt water also creates an environment unsuitable for mangroves (Figure 2.3). In some cases, more enlightened engineers have buried large pipes under new roads to allow the passage of tidal seawater and freshwater runoff to conserve the mangroves.

Mangroves usually grow in flat muddy, insect-ridden areas that, in the past, few people have regarded as worthy of preserving. But in some coastal areas, authorities are now constructing boardwalks through mangrove areas so that more people can appreciate their particular beauty and observe the creatures that live there. In some Pacific islands, local people are taking fee-paying tourists and visitors on canoe tours through mangrove areas near their villages.

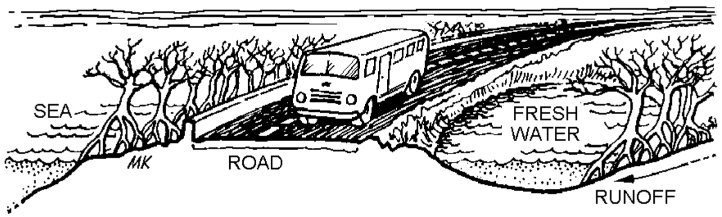


Figure 2.3: Some coastal road constructions that interrupt the mixing of fresh and salt water create an environment unsuitable for mangroves. Mangroves on the seaward side of the road have died because water has become too saline and those on the landward side have died because the water has become too fresh.

Mangroves are now considered to be so important that there have been some attempts to re-establish areas that have been cleared. This involves the hand-planting of mangrove seeds or propagules in suitable areas.

In most South Pacific countries mangroves are protected because of their recognised role in the marine environment. More often, they are protected because of their importance, often as nursery areas, in maintaining populations of fish species that are important food items.

3. Shorelines – beaches and seaplants

The shoreline is constantly changing. In some areas, the coast is being eroded away by the action of waves and currents. In other areas it is being extended by the addition of particles ground from rocks and reefs, or silt deposited by rivers.

Beaches – rivers of sand

Sand stripped from some beaches may be deposited on others. If waves reach the shoreline at an angle, sand is not only carried inshore but along the shoreline in what is called a longshore drift. In Figure 3.1 the longshore drift (from right to left) has deposited sand on the right-hand side of the solid jetty, and has eroded some away from the other side.

The same principle is used in many parts of the world where groynes have been built out at right angles to the shoreline to encourage the build-up of sand.

Beaches take on a form and colour depending on the origin of the sand. Sand formed by the gradual wearing away of rocks may take on a particular colour due to minerals in the rock. In temperate climates white sand is often derived from quartz whereas in the tropics white sand is usually produced from coral and coralline (calcium containing) seaweeds. Some volcanic Pacific islands have striking black sand beaches formed by the wearing away of dark volcanic basalt.

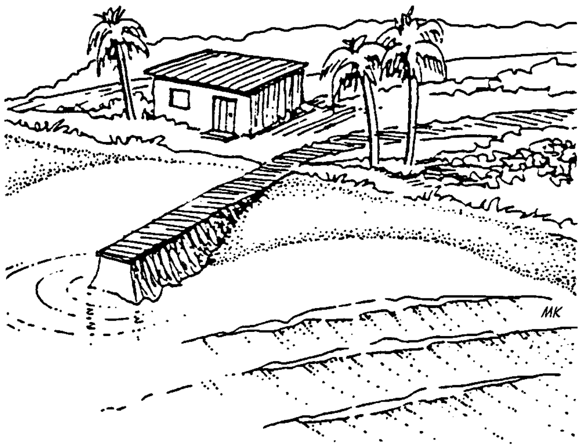


Figure 3.1: The build-up of sand against a jetty in a longshore drift that moves from right to left.

Much of the white coral sand of tropical beaches has passed through the guts of parrotfishes. There are many carnivorous animals that crush and scrape coral, and the colourful parrotfishes are often the most numerous. A parrotfish has fused massive teeth with which it scrapes coral to feed on algae and the coral itself. The remains of the coral skeletons (mostly calcium carbonate) pass through the digestive track as fine particles and these are eventually washed ashore to form sand. Parrotfishes have to consume large quantities of coral to gain quite a small amount of food, and they appear to be continually evacuating clouds of fine coral dust.

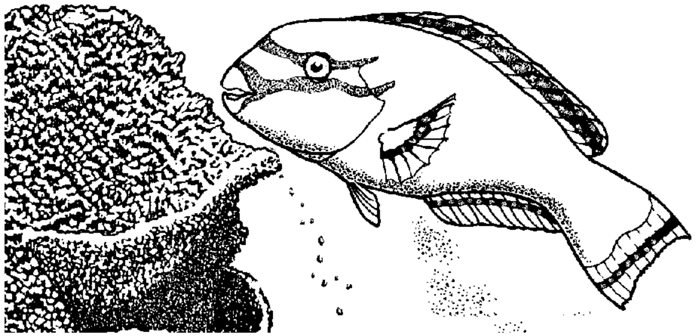


Figure 3.2: A parrotfish feeding by scraping coral *(Montipora).*

Seaweeds – large plants of the sea

The first plants originated in the primaeval ocean and some became adapted for life in fresh water. And it is from here that land plants are thought to have eventually evolved. Luckily for life on earth, some plants remained in the sea and evolved into the various species of marine algae in the world today. The simplest of these are the tiny floating plant cells called phytoplankton, which are possibly the most important plants on the planet (see Section 5). It is their multi-cellular relatives, the marine algae commonly referred to as seaweeds, which are the subjects of this Section.

Seaweeds are very different from land plants. As they can absorb nutrients directly from the surrounding water they have no need for roots. But many species attach themselves to the substrate by means of root-like holdfasts. There are no flowers, and the tips of certain fronds are specialised to produce male and female reproductive cells.

But as in land plants, seaweeds photosynthesize by absorbing light energy from the sun in specialised cellular structures called chloroplasts. And it is the different pigments in the chloroplasts that give seaweeds their colour. The green of chlorophyll is most familiar, but this may be masked by the presence of additional red or brown pigments. Larger seaweeds are grouped, according to their dominant pigment, into brown, red or green algae.

Sunlight penetrates the sea, but the colours making up white light are selectively filtered out with increasing depth. First to go are the longer wavelengths of red – if a diver sustains cut when in deep water, say in depths of over 20 metres, blood appears grayish-brown due to the lack of red light. Last of the components of white light to disappear are the shorter wavelengths of green and blue. And, as the plants use complementary colours for photosynthesis, red and brown algae are more abundant than green algae at greater depths or in shady caves.

Brown algae (Phaeophyceae) are usually the most abundant and conspicuous of the three groups of seaweeds. In cooler waters, these include the giant leathery kelps that form large forests in shallow water. In tropical areas, there are fewer and less striking species than in cooler waters and some are shown in Figure 3.3. A few smaller brown seaweeds attach to coral rubble; these include funnel weed, *Padina,* and the spiny top, *Turbinaria,* which is sometimes boiled and eaten in coastal communities.

Some of the largest of the tropical brown seaweeds belong to the genus *Sargassum.* These have evolved float bladders that, in the case of attached species, keep the plant off the sea floor.

Sargassum can also be found free-living, using its bladders to float and drift on the surface of the sea. The Sargasso Sea, the calm central gyre formed by circulating currents near the West Indies, is named after this seaweed, which forms great rafts in its warm still waters.

Although there are more species of red algae (Rhodophyceae) than all the browns and greens put together, many are inconspicuous or grow in deeper water. Red seaweeds are either filamentous or flattened and may appear red, violet or brown even though they all contain similar pigments.

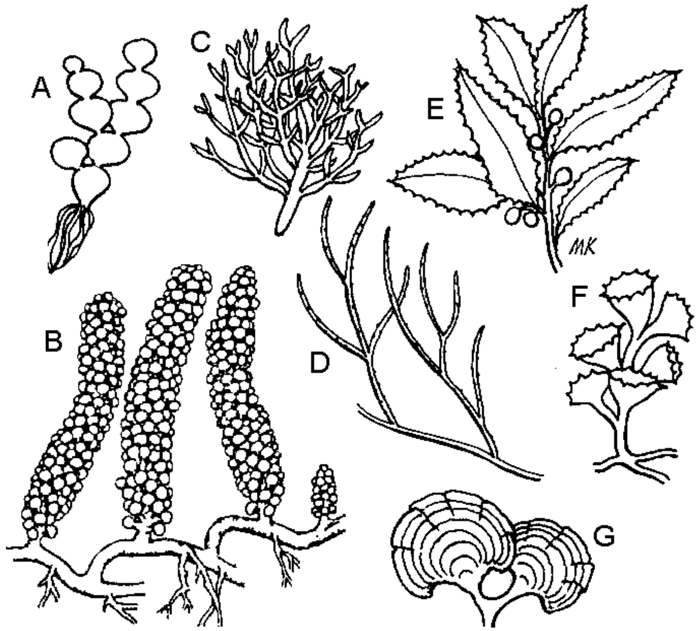


Figure 3.3: Tropical seaweeds.
A) *Halimeda,* B) *Caulerpa* (seagrapes), C) *Gracilaria,* D) *Eucheuma,* E) *Sargassum,* F) *Padina* (funnel weed), and G) *Turbinaria* (spiny top).

Some red and green seaweeds have a remarkable capacity to extract calcium from seawater. The so-called coralline red algae become stiff and even stony with the calcium in their tissues, and some, hardly recognizable as plants, grow as pink incrustations across the surface of rocks.

Several red seaweeds are used as human food. The sheet-like fronds of *Porphyra*, are farmed in Japan where it is called nori - the seaweed wrapped around rice in sushi. In the tropical Pacific, several red seaweeds including *Gracilaria* are eaten by people.

In some islands such as Fiji, *Eucheuma* is being grown commercially on floating ropes before being harvested, dried and processed. The seaweed is used to extract carrageenan, a gelatinous substance used as a thickening agent in many products including dairy foods, sauces, and canned meats.

Green seaweeds (Chlorophyceae) prefer shallow sunlit water. On tropical reefs, bunches of green sea grapes, *Caulerpa,* can often be found growing in pools and crevices among the coral (Figure 3.3). Sea grapes are crisp and tangy and are used as a fresh sea salad in many Pacific Islands. In Fiji, women who collect sea grapes in woven baskets for sale in markets, have the habit of replanting small pieces of the seaweed in new crevices to be assured of future crops.

Several species of tropical green seaweeds extract calcium from seawater. The common coral reef species *Halimeda* shown in Figure 3.3 has branched chains of flat segments that are often calcified and therefore grayish in appearance. As they grow and die, these calcified and stony species contribute considerably to the mass of coral reefs.

Iodine

Seaweeds contain many minerals, including traces of elements that are required by humans in very small quantities. Iodine is one of these, and the lack of it causes the condition known as goitre.

The thyroid gland, a large ductless gland in the neck of all vertebrates, secretes hormones that regulate the rate of metabolism and hence growth and development. In goitre, there is a thyroid hormone deficiency, and the typical swelling of the neck is the result of a futile attempt by the gland to produce more hormone by enlarging itself. It appears that iodine is necessary for the thyroid gland to produce the hormone.

Goitre is almost unknown in countries such as Japan where seaweeds are regularly eaten but is common in some countries where seaweeds are not part of the diet.

Seagrasses – underwater pastures

Flowering plants first appeared on the earth about 100 million years ago, at which stage the dinosaurs were wandering about on dusty, grass-less soil. These new plants with flowers were so successful that some of them invaded the sea where, until that time, large marine seaweeds had held sway.

This invasion resulted in the successful establishment of a small but remarkable group of flowering plants, the seagrasses, in the shallow margins of the sea. By moving to the sea, seagrasses avoided competition with land plants and gained access to constant food – a solution of dissolved nutrients.

Although there are only about fifty different species of sea grasses, these have been so successful that they are found in shallow coastal areas in temperate and tropical regions around the world. Several species are on in the estuaries and lagoons of Pacific islands.

Sea grasses are not true grasses, but they have some grass-like features including leaves attached to a short erect stems and creeping horizontal stems or rhizomes. They also have vascular and root systems like their terrestrial relatives. The leaf blades are long and grass-like in most species, but in some leaves are oval or shaped like broad spearheads (Figure 3.4).

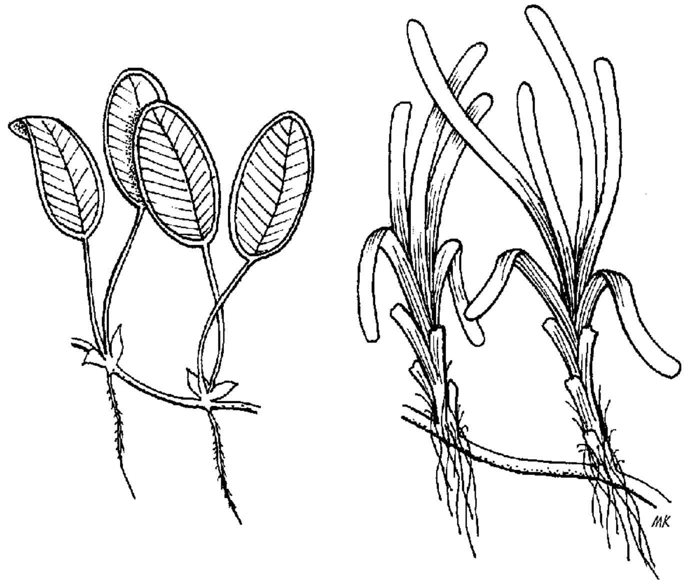


Figure 3.4: The seagrasses (from left), *Halophila* and *Thalassia.*

Amazingly, the flowers produced by most species of sea grasses are fertilized by pollen that can drift through the water. And, if conditions are suitable, sea grasses spread rapidly by means of their network of rhizomes that creep beneath the sand and send up shoots to form vast beds resembling underwater pastures.

Sea grasses play an important role in the coastal processes of many shores. Their networks of roots stabilize drifting sand and their leaves trap more sand that eventually builds up to form sand flats. Beds of sea grass will often extend shorelines and fill in shallow lagoons in this way.

In many low-lying areas and on coral atolls that are often only a few metres above sea level, sea grass beds protect shorelines from wave action and erosion.

In contrast with seaweeds, relatively few animals consume sea grasses – the cellulose that constitutes the bulk of the plant makes it indigestible to most herbivores. However, some can do it, and the largest of these include the green turtle as well as the dugong (see Section 11). Some species of fish, particularly parrotfish, as well as invertebrates such as sea urchins and shrimps are reported to consume sea grasses. However, many animals appearing to graze on these plants may be after the more easily digested fine mat of bacteria and small plants growing on the leaves.

Sea grasses seasonally shed their leaves and these are washed up onto beaches, sometimes in massive quantities, during storms. But all sea grass leaves eventually decay to form detritus that is used as a source of food by a much wider range of marine species.

4. Corals – from coral polyps to reefs

In a short swim across a coral, a greater variety of living things can be seen than in any other place on earth. And the most spectacular of all these things is the coral reef itself.

Coral reefs are among the world's largest natural structures, and are built by the collective efforts of some of the smallest of creatures, coral polyps, generally less than 1 cm in diameter. Most coral polyps form large colonies with a shared skeleton that has a particular size and shape that makes it recognisable as a particular species of coral.

Stony corals and coral polyps

Table corals form broad plates and often grow in giant steps down reef slopes. With their flat plates, like the broad canopy of a tropical rain forest, they capture the maximum amount of sunlight, which is required by all of the different corals shown in Figure 4.1.

Massive corals such as brain coral and boulder coral form the bulk of coral reefs. The more delicate branching forms, such as stag horn coral, fill in gaps between the larger corals and grow in more sheltered lagoons.

Figure 4.1: Some forms and shapes of stony corals. From the left, A) stag horn coral, *Acropora,* B) table coral, *Acropora,* C) brain coral, *Platygyra,* D) leaf coral, *Pachyseris,* E) boulder coral, *Porites,* and, F) mushroom coral, *Fungia*.

The mushroom coral shown in Figure 4.1 is unusual. It exists, not as a colony, but as a solitary huge polyp, up to 20 cm in diameter, and is able to move short distances using its lateral tentacles.

The other corals shown in Figure 4.1 are colonial – that is, they consist of many individual animals of the same kind living together and forming a much larger structure. The bulk of these colonial corals is made up of many millions of dead polyps, and living polyps are found only on their thin outer layer.

Coral polyps are marine animals related to jellyfish and sea anemones. The polyp (Figure 4.2) has a tube-shaped body with a mouth surrounded by small arms or tentacles. And, in the case of hard corals, the polyp produces a stony and cup-like skeleton of calcium carbonate (limestone) around its base.

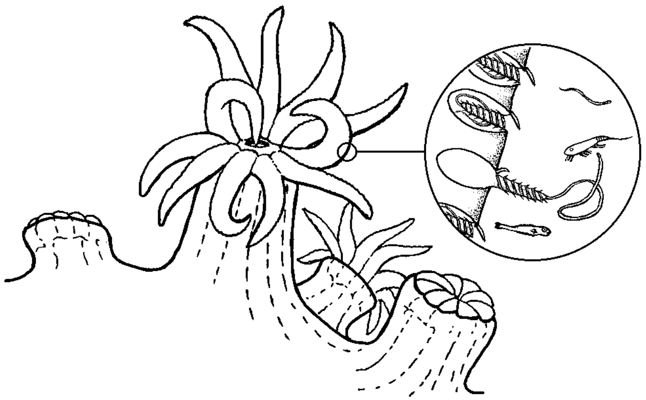


Figure 4.2: Coral polyps. Two polyps are shown extended from their hard skeletons and two are shown retracted. The circle shows an enlarged part of a tentacle of a coral polyp with stinging cells or nematocysts. The harpoon of one cell has been fired.

In most corals, each polyp retracts into its protective cup by day, and emerges to feed at night. Using a diving mask at night will reveal that many corals are covered with a carpet of tiny feeding polyps.

Corals share with their relatives, the jellyfish, the possession of remarkable stinging cells called nematocysts. The stinging cells are distributed on the polyps' tentacles, and each cell contains a coiled thread that can be released with some force. When fired, the thread becomes a poisonous harpoon used to catch small animals, or plankton, drifting by.

Fire corals – stinging hydroids

Most corals do not have stinging cells that are capable of penetrating human skin to a sufficient depth to cause injury. However, those collectively known as fire corals can deliver a strong sting and cause an itchy rash that persists for several days. The toxin is water soluble, and in some cases rubbing the affected area with strong alcohol or methylated spirits will help.

Fire coral is not a true coral, but belongs to a related group of animals called hydroids (Figure 4.5). Many hydroids are soft and feathery but fire-coral is hard and pitted with many tiny pores. Various species grow in thickets with strong vertical flanges or slender branches that often divide at their ends into two parts, and vary in colour from yellow, to green, to ochre.

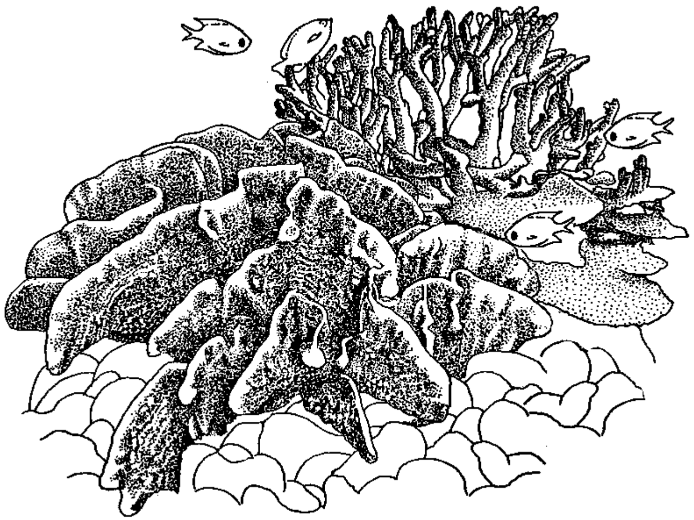


Figure 4.3: Fire coral.
At left the leaf-like, fire coral, *Millepora platyphilla,*
and, at right, the branching fire coral, *Millepora dichotoma.*
Both are mustard coloured with lighter margins or tips.

Besides feeding on small animals that drift within reach, most corals can feed indirectly from sunlight. Microscopic plants, called zooxanthellae, live inside the coral's tissues where they use sunlight, and nutrients from the water, to produce food. The food is shared with the coral, which, reciprocally, provides shelter for the small plant cells. This is an example of symbiosis - a relationship between two different organisms that live together for the benefit of both.

Because of their reliance on zooxanthellae, most corals, like plants, require sunlight for photosynthesis and can only live in clear, shallow, brightly lit waters.

Corals in deepwater

Some corals have no symbiotic plant cells and therefore do not require sunlight. The so-called black corals (Antipatharia) can live at great depths thereby avoiding competition with light-requiring stony corals. In life, black corals (Figure 4.4) are brown or yellow. and the dense black skeleton underneath is the material used to make jewelry. The hard varieties, suitable for cutting and polishing, are gathered by SCUBA divers in depths below 50 metres, where the time that a diver can spend collecting is very short.

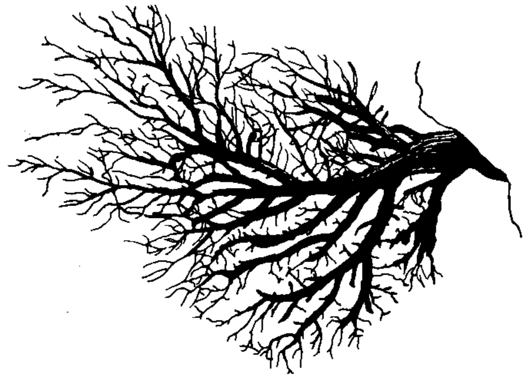


Figure 4.4: The deepwater black coral, *Antipathes,*
used in making polished jewellery.

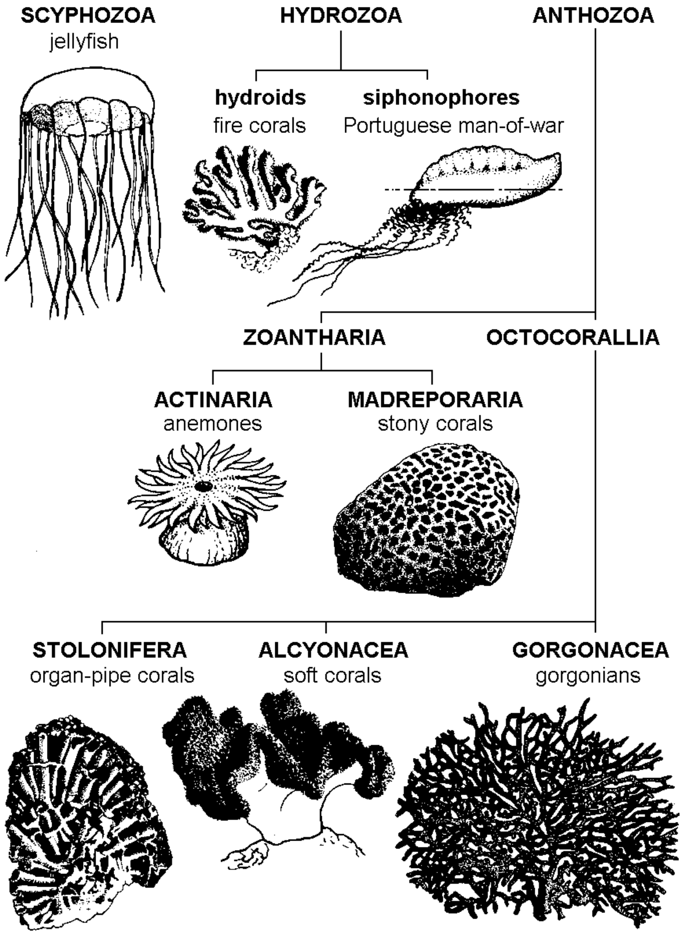


Figure 4.5: Cnidarians. Jellyfish, hydroids, anemones and corals are related and placed in this large group

Flowers of the reef - anemones

An anemone is like a large coral polyp, but has a fleshy body without a limestone skeleton. It has a tubular body with a mouth surrounded by tentacles. The tentacles sting small animals that stray within their reach, and these are transferred to the central mouth. But not all animals are susceptible to the anemone's stings. The clown fish lives amongst the stinging tentacles, from which it appears to be protected by mucus on its skin. The fish leaves to get food but rushes back within the tentacles at the first sign of danger. As the anemone also benefits by feeding on scraps of food dropped by the clown fish, this is an example of symbiosis.

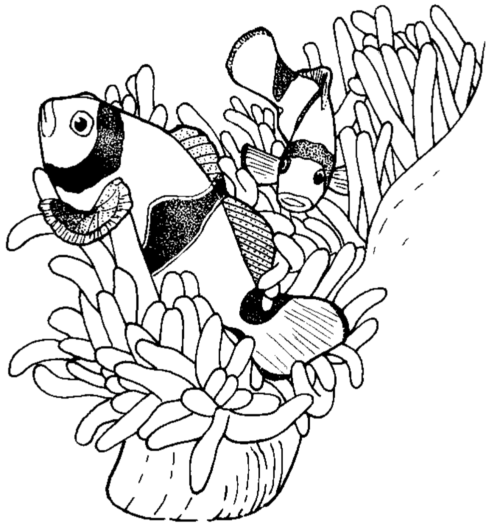


Figure 4.6: Anemones with their resident clown fish.

Soft corals and gorgonians - octocorals

The Octocorals (see Figure 4.5) are all colonial, and are so-named for the eight tentacles surrounding the mouths of their polyps. These include the soft corals and the gorgonians (Figure 4.7).

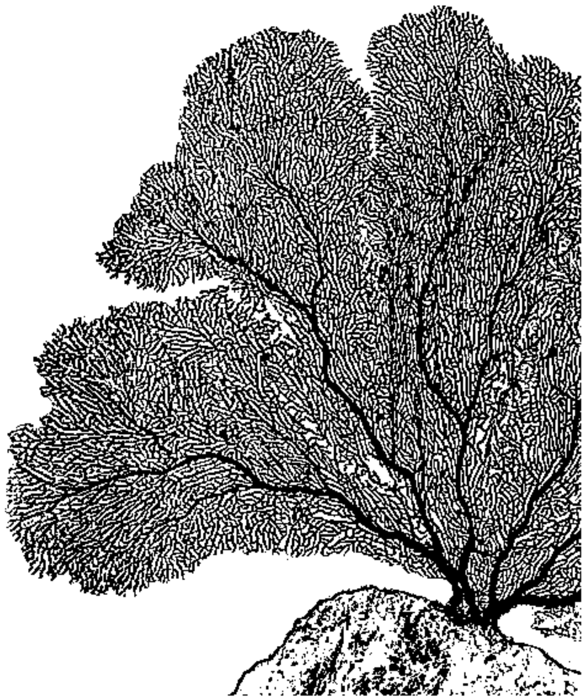


Figure 4.7: A gorgonian sea-fan, *Subergorgia.* Coloured red, yellow or violet, the fans grow to over 3 metres in width.

A large gorgonian or sea-fan is one of the most spectacular of underwater sights. Their polyps are distributed over horny and flexible skeletons, which form fan-like branches of intricate meshes. The branches are often set perpendicular to the water movement to allow the polyps maximum exposure to drifting food.

One particular group (Alyconaria) has members that do not secrete hard skeletons but have tissues supported by silica or calcareous spicules. These are the so-called soft corals, shown in Figure 4.5, that are usually rubbery and bush-like.

Coral reefs – the world's largest natural structures

Every year, for just a few nights in late spring or early summer, corals put on a spectacular display. In a brief but highly synchronised spawning event, corals release countless millions of eggs and sperm bundles.

A night dive at this particular time of the year resembles swimming through an upside down snowstorm. At the sea's surface the bundles break apart and sperm, driven by tadpole-like tails, seek out the eggs. After fertilisation, the eggs hatch into larvae and the sea's surface appears to be covered in a fine red dust of developing eggs and larvae.

The advantage of all individuals spawning at the same time is that the chance of sperm meeting egg is maximised. Coral larvae drift on the surface of the sea for several days before sinking to the sea floor. Of the myriad larvae released by the parent corals, countless millions are eaten by surface feeding fish. And, of those remaining, only a few manage to reach shallow water and settle on suitable hard surfaces, to grow into new polyps. These fortunate few polyps then divide to form new polyps and gradually a new colony of coral is formed.

The requirements for reef-building corals to grow are quite specific. First, the water must be shallow and clear enough for sufficient sunlight to reach the plant cells growing within the polyps. Second, the temperature of the water must be above 20 degrees centigrade. Any hard surface meeting these requirements, providing it is within reach of drifting coral larvae, will soon obtain a covering of corals.

In the formation of a coral reef, polyps die leaving rock-like skeletons of calcium carbonate, and new polyps grow on top of the remaining skeletons. The coral reef thus continues to grow outwards and upwards with each generation of polyps. The major part of the reef, below the outer growing layer of living polyps, consists of the skeletons of countless millions of polyps - one kilogramme of coral rock may contain over 80,000 polyp skeletons.

Although the growth of a coral is slow, the combined effort of a myriad polyps have produced some of the world's largest natural structures – these include the Great Barrier Reef of Australia and the extensive barrier reefs of New Caledonia.

In general, there are three basic types of coral reefs - fringing reefs, barrier reefs and atolls – and examples of these can be found on Pacific Islands with different geological ages. Continental islands may be formed in areas of uplift where the earth’s continental plates collide and raise the sea floor, and volcanic islands are formed where subterranean action creates underwater mountains that rise above the surface of the sea (see Natural events in Section 13).

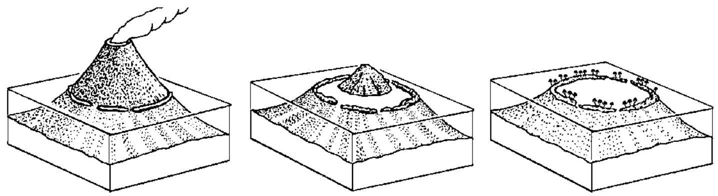


Figure 4.8: The evolution of coral reefs from fringing reefs (at left) to barrier reefs to atolls.

One explanation of how the different types of reefs evolve is based on the gradual sinking of a newly formed volcanic island over many thousands of years. As long as the newly formed island is in tropical waters it would soon acquire a fringing reef of coral.

As the island slowly sinks and the water rises, the reef front of the fringing reef around the island grows upwards. Eventually a lagoon will form between the sinking island and the growing coral, which then becomes a barrier reef around the island. If the island continues to sink and drops beneath the sea surface, the barrier reef continues to grow upwards to form a circular atoll (Figure 4.8).

Corals have many predators. Often the most visible of these are the many species of parrotfish (Figure 3.2) that scrape away at the surface of corals to feed on the coral polyps.

The most publicised predator of corals is the crown-of-thorns sea star (Figure 4.9), which has been accused of laying waste huge areas of coral reefs. The sea star crawls over the corals and uses its extendable mouth to suck up the polyps from their protective cups.

There is controversy over what causes the destructive plagues of crown-of-thorns, which have been said to destroy reefs at rates of 5 kilometres a month. Perhaps there are natural fluctuations in population sizes, or perhaps surges in their numbers have been caused by pollution from nearby coastal areas. The over-collecting of some of their molluscan predators has also been blamed, and the large trumpet triton, *Charonia tritonis,* shown later as the larger of the two tritons in Figure 8.8, is one of these.

A thorny problem

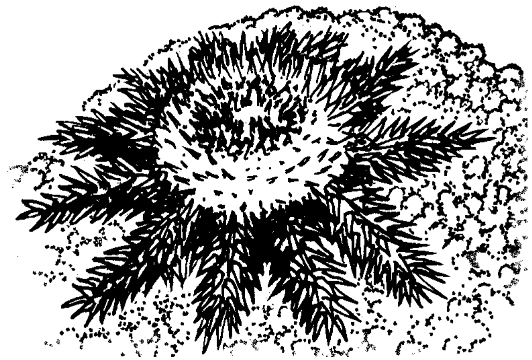


Figure 4.9: The crown-of-thorns sea star, *Acanthaster planci.*

The sea star has short spines that are toxic. In some Pacific Islands there is a traditional but unproven remedy for people who have been pricked by the spines; the wound is placed over the mouth of the upside-down sea star, which is then believed to suck out its own poison.

Although corals have many predators, the activities of people present the greatest threat to coral reefs. Corals are collected for sale as souvenirs and coral blocks are used for building. Harbour dredging and coastal building projects release silt into the water and this blocks off sunlight or smothers the corals.

Burrowing in coral

Corals support a wide range of burrowing animals and some of the most striking of these are the burrowing species of giant clams and the colourful Christmas tree worms.

Christmas tree worms live in tubes embedded in hard corals. Strictly, the worms do not bore into the coral, but the coral grows up around their tubes and only the openings are exposed. And through these tube openings, extend double spirals of the most beautiful feathery tentacles. Different individuals with either bright red, blue, or yellow tentacles may be found on the same coral head and, interestingly, one individual can produce offspring with any one of these different colours.

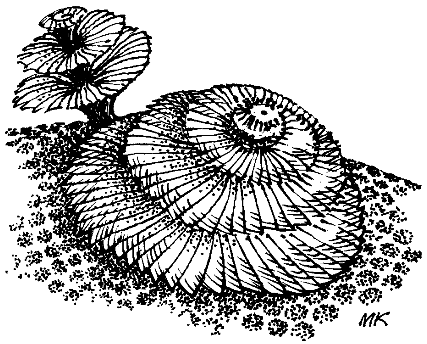


Figure 4.10: Christmas tree worms, *Spirobranchus giganteus,* embedded in hard coral. The feathery and spiralled tentacles may be either red, blue, green or yellow.

A coral reef is part of a complex ecosystem that provides food and shelter for a greater variety of animals and plants than most other natural areas in the world. And many of the species found on, or associated with coral reefs are important food items for coastal communities. In addition, coral reefs protect coastlines and villages, particularly from large ocean waves created by cyclones, and are the source of the sand that builds up on beaches.

In some areas, corals are being destroyed by the use of poisonous chemicals and explosives for fishing (see Section 12). Coral reefs that have been destroyed by the use of explosives are no longer able to support populations of fish, and the reef may not recover for many years. Dynamited reefs in the Philippines, for example, have taken an average of 38 years to recover after dynamiting has been stopped.

5. Relationships between organisms and ecosystems

Within the various marine ecosystems described previously there is a flow of material and energy from one living organism to another. This flow of food can be represented by a food web – a series of lines connecting each living organism to its food.

Foodwebs – the movement of food

Energy from the sun and food material in the sea (mainly nitrates and phosphates) are used by plants to form tissue through the process of photosynthesis. This is referred to as primary productivity. Most primary productivity in the sea is due, not to large plants such as seaweeds and seagrasses, but to a myriad microscopic plants called phytoplankton. These tiny plant cells drift in the sea and are grazed upon by small animals called zooplankton. Plant material is eaten by animals which themselves are eaten by other, usually larger, animals. This flow of energy and food is shown as a food web in Figure 5.1.

Energy pyramids and trophic levels

The flow of energy through food webs can also be illustrated as the energy pyramid shown in Figure 5.2.

The first or lowest trophic level in the energy pyramid, the primary producer level, consists of marine plant material.

This plant material is fed upon by animals in the next trophic level (the herbivore level) and these herbivores become prey species for carnivorous fish (the carnivore level). As some fish feed on other carnivores, there may be several trophic levels of carnivores.

At each level most of the total weight of material (the biomass) or energy is lost. Animals use most of their food energy for bodily functions, and are able to convert only a fraction of the energy taken in to growth that may be passed on to the next trophic level. There is, therefore, a decrease in total biomass at each succeeding trophic level.

The biomass values shown to the right of the energy pyramid in Figure 5.2 arbitrarily assume a 10 per cent level of ecological efficiency – that is, the energy passed from one trophic level to the next. It therefore takes one tonne (or 1000 kg) of plant material to produce one kilogram of a higher level carnivore such as a snapper.

Figure 5.1: A simplified, tropical, marine food web.

Plants such as mangroves **(1)** and seagrasses **(2)** use sunlight to produce plant material from carbon dioxide and nutrients during photosynthesis. Plant material is eaten by herbivorous animals such as triggerfish **(3)** and sea urchins **(4).**

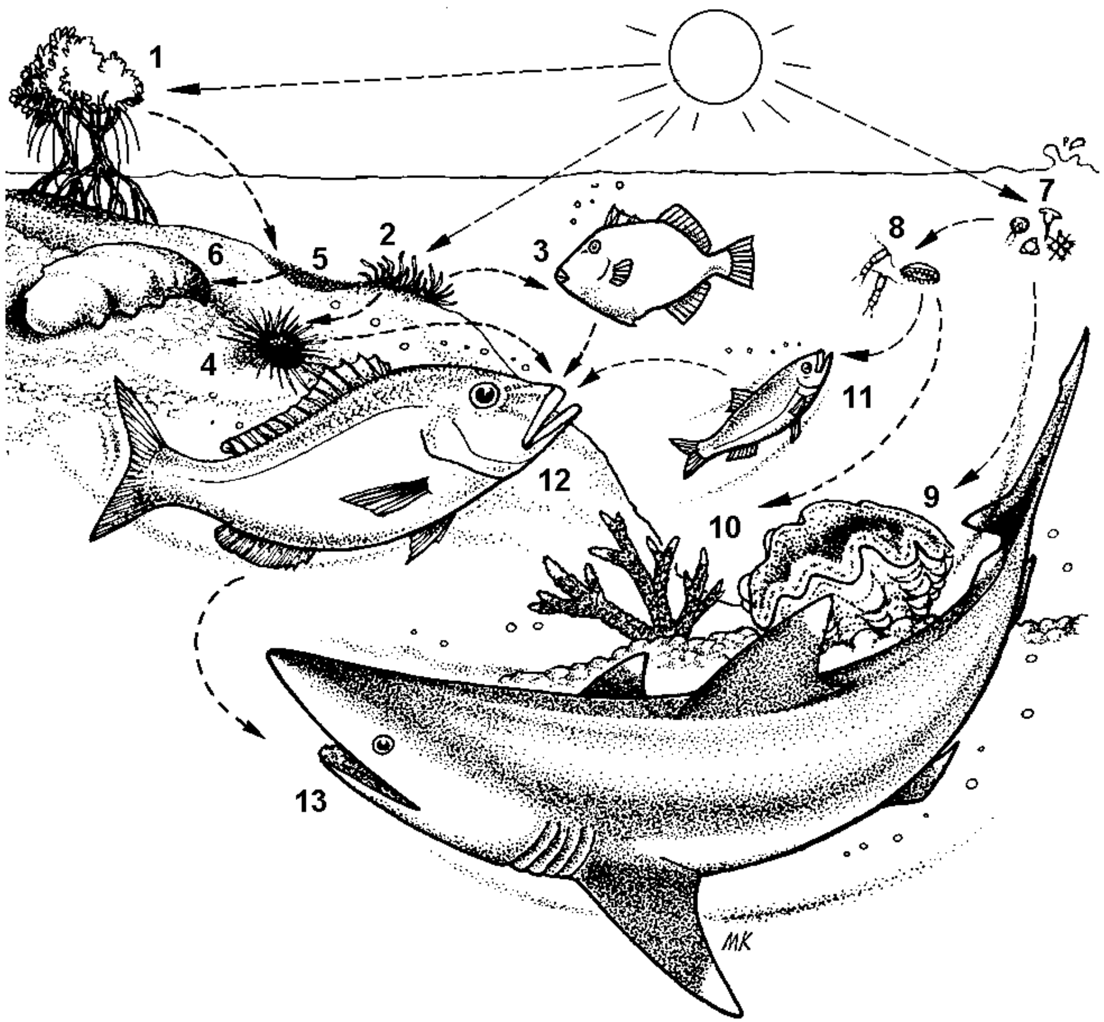
Plants and wastes from animals are broken down by bacteria to form organic material called detritus **(5)** that is consumed by a wide range of animals, including the sea cucumber **(6)**.

Microscopic plants or phytoplankton (greatly magnified in **7**) drift near the surface of the sea, and are eaten by small floating animals called zooplankton (magnified in **8**).

Some animals, including the giant clam **(9)**, actively pump seawater through their shells to filter out phytoplankton for food.

Zooplankton are consumed by carnivores such as corals **(10)** and sardines **(11)**.

Fish, including emperors **(12),** eat a wide range of smaller fish, and are themselves hunted by top carnivores such as sharks **(13).**



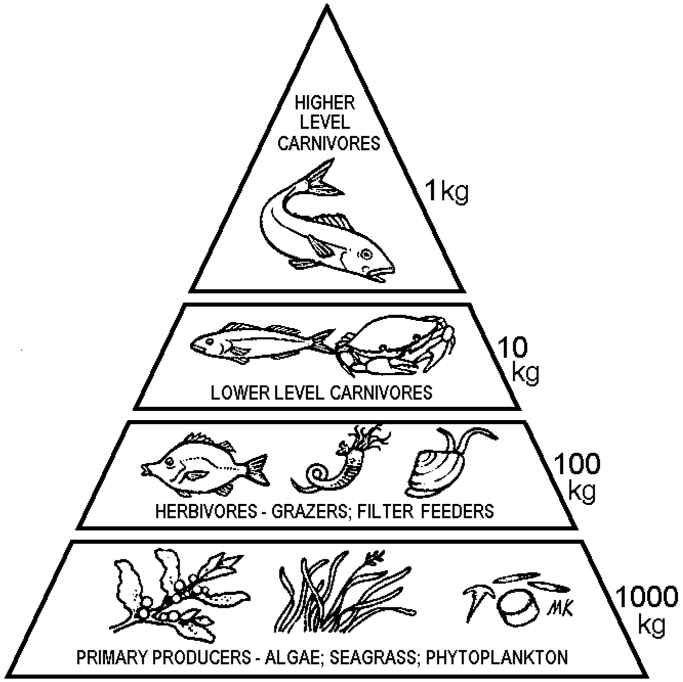


Figure 5.2: An energy pyramid

The energy pyramid suggests that animals at higher trophic levels are not able to maintain very large populations. A top carnivore such as a large tiger shark is, perhaps thankfully, not common at all – a shark needs to swim over a huge territory in order to have access to all the food that it requires.

Conversely, for a given quantity of plants (or amount of primary productivity), the environment is able to support a much greater biomass of animals at lower trophic levels than at higher trophic levels. In many Pacific inshore environments, for example, there are large numbers of small clams and cockles, which filter phytoplankton, and therefore occupy a low trophic level.

A much larger population of people can be supported on a diet of clams than on a diet of carnivorous fish. The trouble is that most people would rather eat snapper and tuna than clams and cockles.

A terrestrial analogy is the hypothetical situation where two fields of rice can be used to feed twenty pigs, which can used to feed two people for a particular period of time. Alternatively, the two fields of rice could feed twenty people (who were prepared to be vegetarians) for the same period.

The view that the seas are an inexhaustible larder of food for the increasing populations of the world is plainly untrue.

Studies on the primary productivity of marine plants and food chains have been used to estimate the capacity of the oceans to provide seafood. Such studies not only confirm the obvious, that the sea's fisheries resources are finite, but suggest that the maximum world catch from conventional resources is about what we are catching at present – less than 100 million tonnes of seafood each year.

A consideration of food webs emphasises the fragility of marine ecosystems. Because ecosystems are connected through food webs and migration, human activities that badly affect one ecosystem may affect other types of ecosystems, even those some distance away. And reducing the numbers of one marine species by overfishing or by destroying its habitat may affect many other species.

Biomagnification – ciguatera and red tides

Although the biomass of living creatures decreases up the energy pyramid (from plants to higher order carnivores), the concentration of some substances contained in living material may increase. That is, if plants containing toxic material are eaten by herbivorous fish, the fish may get to contain more toxin, and the predators of these fish even more so. This effect is called biomagnification.

Ciguatera poisoning is common in many tropical areas, and considerable numbers of people suffer and sometimes die from eating affected fish. Tuvalu, for example, has one of the highest rates of ciguatera poisoning in the world, with about 10% of the population of the island of Niutao being affected each year.

The sequence of events leading to an outbreak of ciguatera is illustrated in the cartoon shown in Figure 5.3; this cartoon has been used to raise community awareness in Pacific islands.

A microscopic plant known as *Gambierdiscus toxicus,* which belongs to the phytoplankton group known as dinoflagellates, occurs naturally as a film on corals and seagrasses. This small plant contains a chemical precursor that is converted to poisonous ciguatoxin in the livers of the herbivorous fish feeding on it.

Usually the abundance of *Gambierdiscus* is low but, like other microscopic plants in the sea, their numbers increase dramatically when there are high levels of nutrients available. This happens during the wet season when nutrients are washed from the land by rain and during cyclones when nutrients are released from damaged shorelines and coral reefs. In many cases, outbreaks of ciguatera have been associated with human activities such as harbour dredging and the use of underwater explosives.

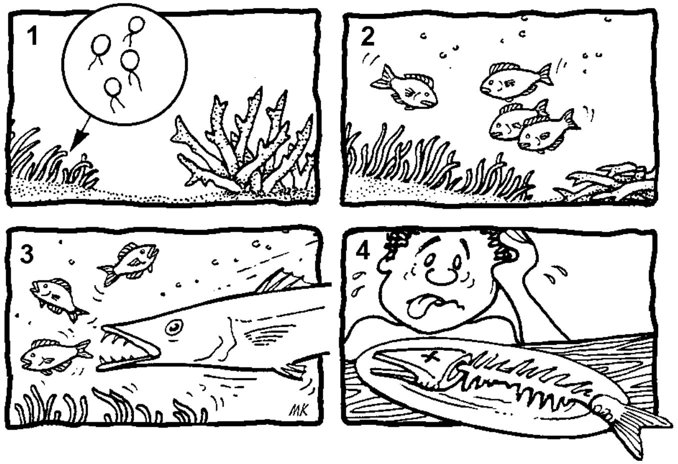


Figure 5.3: The sequences of events leading to ciguatera poisoning.

1) The dinoflagellate, *Gambierdiscus toxicus* (magnified in the circle) occurs as a film on corals and seagrasses,

2) nutrients (say from the damaged coral at right) are released into the sea, the abundance of *Gambierdiscus* increases, and small herbivorous fish become toxic,

3) toxins are passed on to predators such as barracudas, and,

4) people eating these usually edible fish become affected by ciguatera.

In such high nutrient conditions, the number of *Gambierdiscus* increases rapidly by simple cell division – 1 becomes 2, 2 become 4, 4 become 8 and so on. It only takes 20 such steps to produce over one million individuals. Schools of small fish graze on the abundant *Gambierdiscus* and, in doing so, concentrate the poisonous material within their own bodies.

Carnivorous fish feed on the schools of smaller fish, and further concentrate the toxic material in their own flesh. A large barracuda, taking advantage of the abundant food, could snap up several of the smaller carnivorous fish, and, in one meal, gain the toxins accumulated by the prey species over their entire life-spans.

People eating fish affected by ciguatera suffer from tingling, numbness, and muscle pains. One odd effect is the reversal of temperature perceptions – hot feels cold and vice versa. And sometimes the condition is much more serious.

The most dangerous fish to eat are large predatory reef fish including moray eels, some red snappers, barracudas and Spanish mackerels. Many of these fish become toxic only during the wet season or when there has been a recent cyclone, dredging activities or coral damage. Oceanic fish such as tuna, and other fish that live in areas distant from the coral reef ecosystems where *Gambierdiscus* grows are usually safe at any time of the year.

Unfortunately, and in spite of widespread folklore on the subject, there is no reliable, cheap test to determine whether or not a particular fish is ciguatoxic.

One common belief is that toxic fish can be recognised by exposing a fillet of the fish to flies – the flesh is regarded as poisonous if the flies avoid it. Another story is that toxic fish can be recognised by placing a silver coin on the flesh – if the coin turns black, the flesh is not safe to eat. Unfortunately these tests, and many other widely trusted ones, do not work.

Red tides and paralytic shellfish poisoning

In certain conditions, phytoplankton species increase in numbers, or bloom, to such an extent that the density of their bodies colours the sea red. Some of these are toxic dinoflagellates, such as *Gonyaulax,* and are ingested by filter-feeding molluscs such as cockles, clams and mussels (see Section 8). Through the food chains the toxins are passed on to, and concentrated in, fish feeding on the shellfish.

Sometimes red tides poison thousands of fish. And humans feeding on contaminated shellfish suffer the condition known as Paralytic Shellfish Poisoning (PSP), which, in the most severe cases, results in respiratory paralysis. Red tides appear to be natural phenomena occurring in response to seasonal increases in nutrient levels in the sea. It is believed that the Red Sea was so-named because of frequent dense blooms of a reddish blue-green alga.

The incidence of red tides may be increasing for two reasons. First, nutrients derived from fertilizers and sewage reaching the sea are increasing. Second, plankton species are being carried into different countries from distant ports in the ballast water of freighters.

6. The classification and diversity of marine life

Marine environments in tropical inshore regions provide food and shelter for a greater variety of animals and plants than most other natural areas in the world. The following sections describe some of the species found in the tropical Pacific Ocean and emphasise not only those important in marine ecosystems but those that are used as food by coastal communities. In order to appreciate the huge array of plants and animals it is first necessary to look at biological classification.

Biological classification – naming things

The study of biological classification, or taxonomy, involves grouping living things according to relationships that exist in nature. The basic unit is a species - a group of similar, related individuals that are capable of breeding with each other. Species are recognised as such on the basis of having similar characteristics and larval stages, as well as having what is believed to be a common ancestor, perhaps many millions of years ago.

The following example is based on the classification of the tropical saucer scallop, which is fished commercially in the lagoons of New Caledonia.

Scientifically, the scallop is referred to by its Genus name (beginning with a capital letter) followed by the species name - *Amusium balloti.* The benefit of using a scientific name (of which there is only one) becomes obvious when one considers that there are at least five common names in use for this species – tropical saucer scallop, moon scallop, sun scallop, mud scallop and Ballot's saucer scallop.

Kingdom: Animalia
- all animals

Phylum: Mollusca
- all unsegmented (often shelled) animals
with similar larval stages (all molluscs).

Class: Bivalvia
– all molluscs with two shells (all bivalve molluscs)

Order: Pterioida
– all bivalves with shells joined by one muscle etc
(all oysters, scallops etc)

Family: Pectinidae
– all bivalves with fan-shaped shells etc (all scallops)

Genus: *Amusium*
– all scallops with thin circular shells (saucer scallops)

Species: *balloti*
– the tropical saucer scallop

The tropical saucer scallop is shown in Figure 6.1 with a relative, the cooler-water southern scallop, which belongs to the same family but is sufficiently different to be placed in a separate genus.

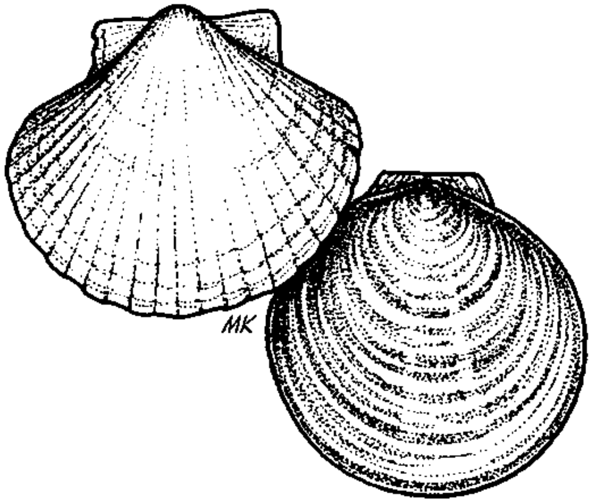


Figure 6.1: The saucer scallop, *Amusium bolloti,* and the southern scallop, *Pecten fumatus.* Both species reach over 100 mm.

Diversity – the numbers of species

The diversity (or different kinds) of inshore marine species in Pacific island countries varies with both latitude and longitude. It is a general rule in biology that diversity decreases with increasing distance away from the equator. Thus, a reef off the coast of Fiji is likely to have many more different species of marine life than a reef off the coast of New Zealand.

Diversity also decreases from west to east across the Pacific with increasing distance away from an area of very high diversity in the Indonesian/Philippines area. This area is believed to be a centre of speciation (where many different living things first came into existence many millions of years ago). Floating seeds from plants and larvae from animals drifting away from their origin in this area were more likely to reach nearby islands in the western Pacific than the more distant islands in the east.

Mangroves, for example, produce seeds (or propagules) that can drift in the sea for varying lengths of time. The species with seeds that sink within a short time are unlikely to be able to travel far across the ocean. Species with more durable floating seeds are more likely to be able to reach distant shores and grow into trees. As a result of this there are 45 different species of mangroves in Papua New Guinea, 33 in the Solomon Islands and only 7 in Fiji.

Similarly, the number of different species of corals decreases markedly from west to east across the Pacific; there are 500 coral species on the Great Barrier Reef, 300 in New Caledonia, 120 in French Polynesia and 15 in the Gulf of Panama.

Diversity is also related to the type of island. Islands with a greater number of different ecosystems are more likely to have a larger diversity of living things. Fiji, for example, with its large rivers and estuaries has some estuarine species that are not found in atoll islands such as Tuvalu.

In the open ocean, tropical waters are noted for the low abundance of marine life. Generally, there are small quantities of nutrients for plankton, which results in only small numbers of fishes. However, there are exceptions to this and one is the case where there is an upwelling - deep water that moves up to the surface, bringing up nutrients that would otherwise be locked up in the depths.

One of the most important upwellings in the western Pacific is the one resulting from the South and North Equatorial Currents moving apart - one north towards Japan, and the other south down the east coast of Australia (Figure 6.2 and under Natural events, Section 13). As these two currents move apart, deep water is drawn up to replace surface waters. This upwelling makes nutrients available for phytoplankton and through the food chains results in a high abundance of pelagic fishes such as tuna.

The different kinds, or variety, of plant and animal life and ecosystems in a given area is referred to as its biodiversity. Biodiversity refers to all variability in life, from the minute genetic level (the basic building blocks of life) through to the large scale of complex processes within ecosystems (processes involving food webs have been discussed in the previous section). The oxygen that we breathe, the food we consume, the fuel we use, are all directly related to biodiversity. These are some of the reasons why preserving biodiversity is becoming increasingly regarded as important.

Reducing biodiversity by intensive agriculture (in which one species is farmed at the expense of all others) or by overfishing (in which marine species are depleted) or by the destruction of ecosystems (say by coastal development) may have far-reaching effects. Destroying one component of an ecosystem or reducing the numbers of one marine species may affect the entire system. In addition, because ecosystems are connected through food webs and migration, human activities that badly affect one ecosystem may affect other types of ecosystems, even those some distance away.

The Pacific island region with its variety of tropical ecosystems has more species than most places on earth. The following sections of this book describe common species that belong to one of four large scientific groups. The invertebrate groups include molluscs (such as clams, sea-snails and squids), crustaceans (shrimps, lobsters, and crabs), echinoderms (sea cucumbers and sea urchins), and vertebrates (fish, turtles and mammals).

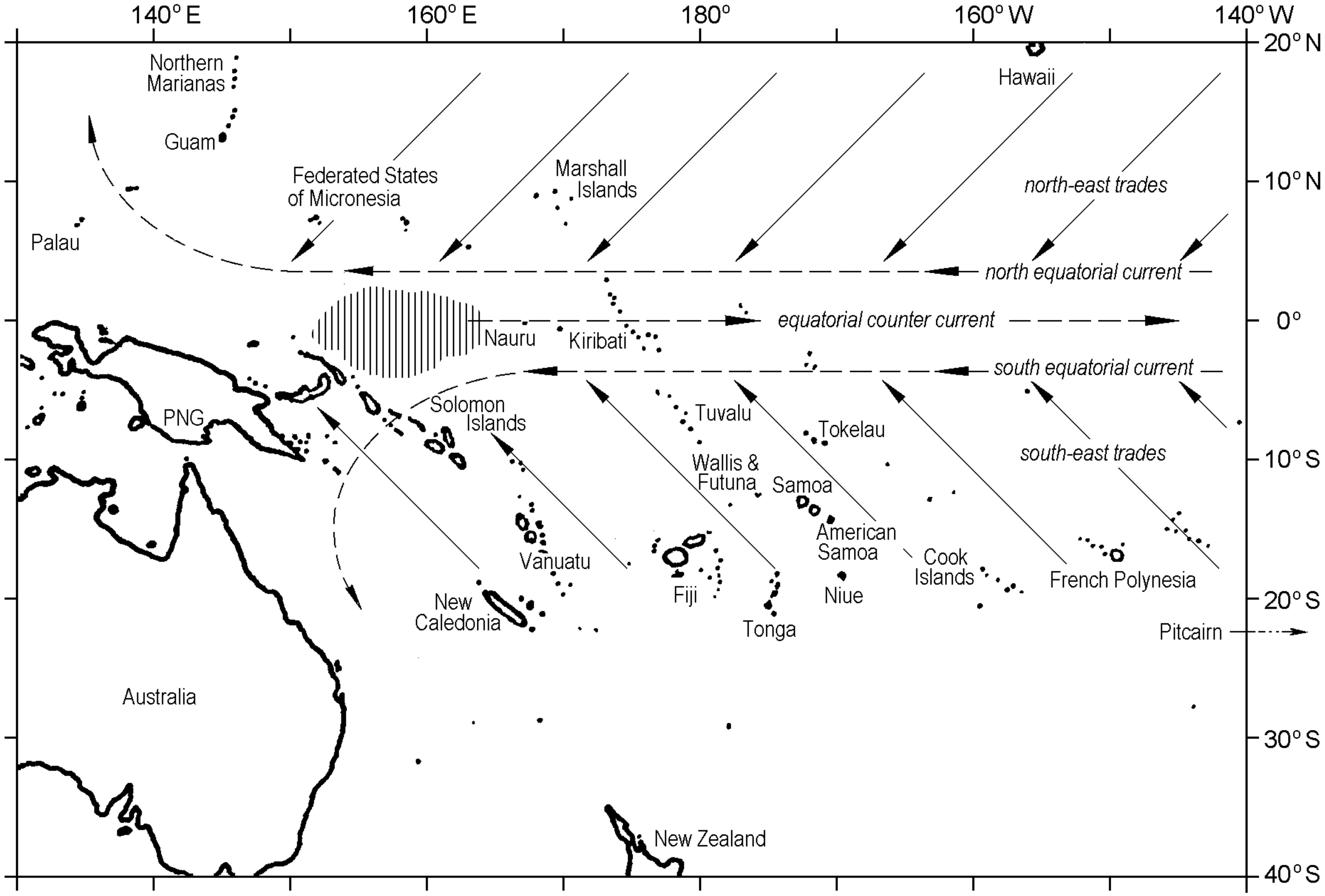


Figure 6.2: The Pacific island region. The northeast and southeast trade winds are shown by oblique lines with arrow heads. The winds drive the South and North Equatorial Currents (dashed lines) – these move apart to form an equatorial upwelling. The centre of the upwelling is shown by vertical line shading.

7. Crustaceans – shrimps to coconut crabs

Over 26 000 marine animals including prawns, shrimps, lobsters and crabs, together with such animals as sea lice and barnacles, are crustaceans (Figure 7.1).

Crustaceans typically have jointed legs attached to a segmented body that is covered with a hard shell, or exoskeleton. The shell is made from chitin (a flexible horny substance), which is hardened with calcium carbonate (the main constituent of chalk).

The possession of a hard inflexible shell prevents crustaceans from growing with a continuous increase in size as other animals do. In order to grow in size, a crustacean must periodically cast off its restrictive shell in a process called moulting, and expand in the short time before a new and larger shell hardens (see Box "New shells for old" and Figure 7.3).

Smaller crustaceans

There are many smaller species of crustaceans that spend their entire lives drifting in the open seas as part of the plankton. The marine copepod *Calanus,* for example, shown at the top of Figure 7.1 is one of the most abundant animals in the world.

Another planktonic crustacean is the shrimp-like euphausid or krill, which grows to six centimetres in length (Figure 7.1). Krill are the main food item of baleen whales, which sieve them from the water in massive quantities. The blue whale, described in Chapter 11, can devour as much as 8 tonnes of krill each day.

Although superficially mollusc-looking, the acorn barnacle and the gooseneck barnacle (second from the top in Figure 7.1) are crustaceans that attach themselves to hard surfaces. Their "shells" are made up of plates like those covering a shrimp or a lobster, and its limbs are reduced to feathery appendages used to waft microscopic food into its mouth.

Turn over some wet seaweed stranded on a beach, and there is likely to be small animals resembling fleas, hopping away trying to get back into the dampness that they require. Sea fleas have bodies that are flattened from side to side, and are included in the scientific group known as amphipods (Figure 7.2). Many sea fleas live on beaches where they feed on plants and animals washed up by the waves. And, as their role in life is to clear beaches of all organic material, they sometimes nip at people sitting on the sand.

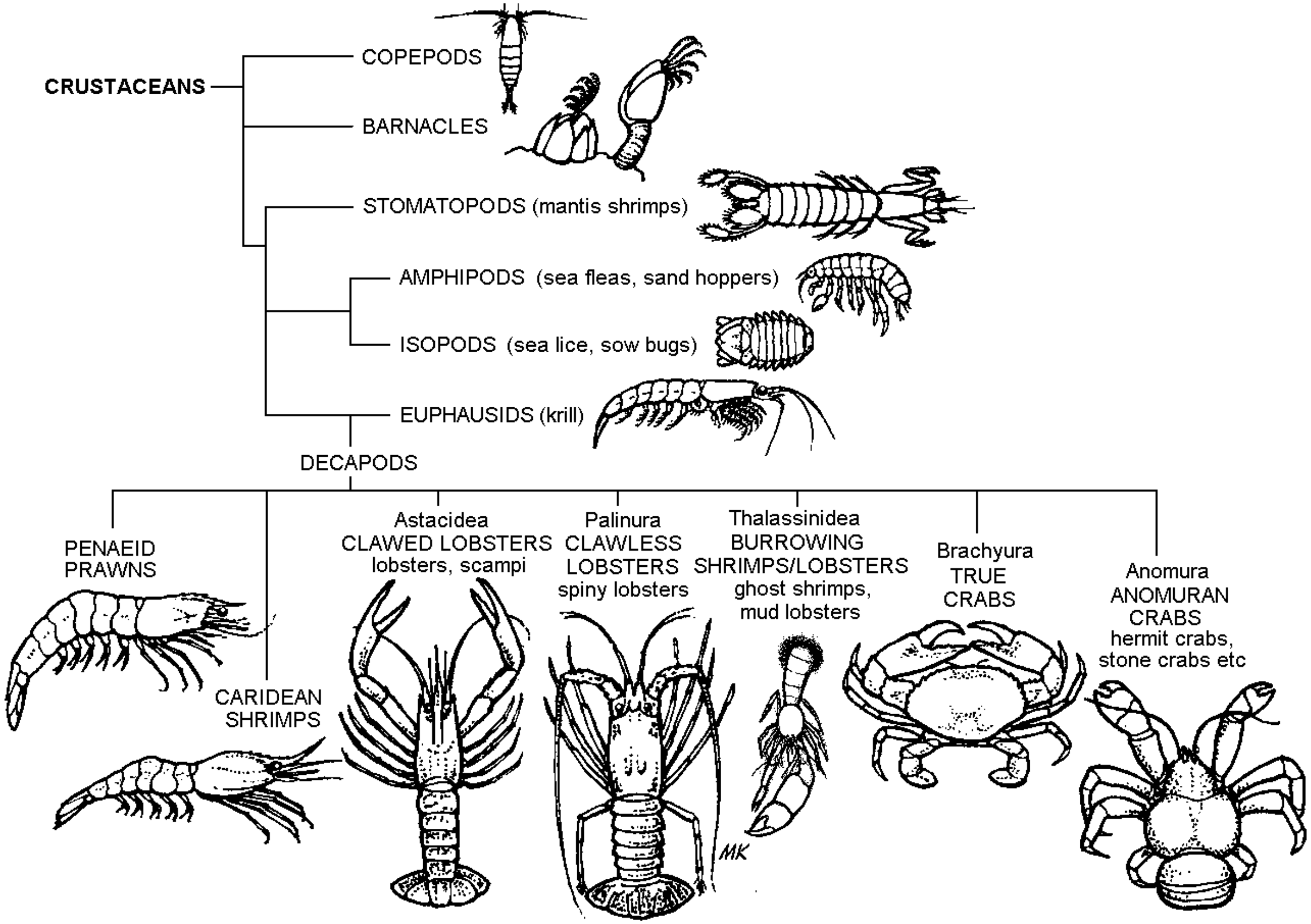


Figure 7.1: Types of crustaceans.

Sea lice or sand lice are flattened from top to bottom and belong to a group of largely marine animals called isopods (Figure 7.2). Their common names result from a superficial resemblance to the lice that infest places of careless human habitation. And, because of this, isopods have an unsavory reputation that is largely undeserved.

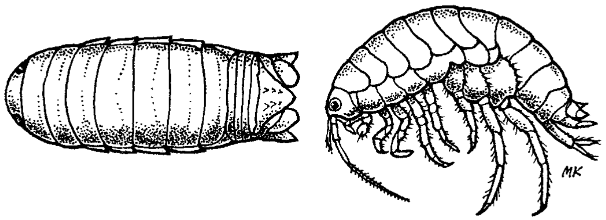


Figure 7.2: Sea fleas and sea lice. From left, an isopod (sea louse, sand louse, and an amphipod (sea flea, beach flea or sand hopper)

Some species of marine isopods are often so numerous and voracious that they are capable of stripping bait from fishing lines and traps in a short time. Although most isopods are only a centimetre or so long, some deepwater species recorded from Papua New Guinea are up to 35 cm in length.

A few isopods are parasites on other crustaceans and fish. On fish, they attach to the gills, tongues and fins, or burrow into their bodies. Some specialised isopods such as the gribble are wood borers.

Mantis shrimps or stomatopods (Figure 7.1) are common on reefs. The common name comes from its legs, which are similar to those of the insect known as a praying mantis.

New shells for old – the moult cycle

Before a crustacean moults, a new soft-shell forms beneath the older and existing hard shell. The old shell then splits and is shed by the soft-shelled crustacean. After the crustacean casts off its old shell, the animal takes in water and expands before the new and larger shell gradually hardens.

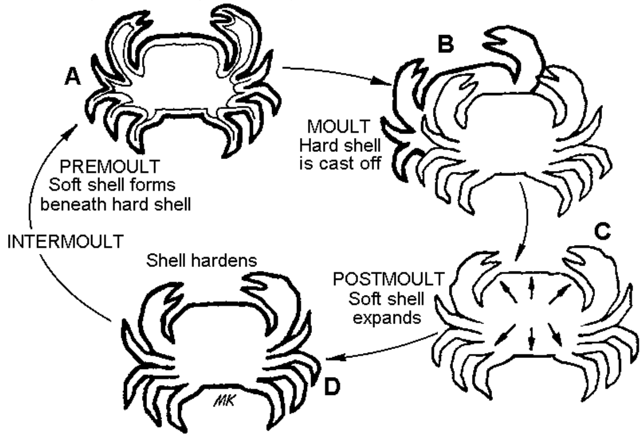


Figure 7.3: The stages of the crustacean moult cycle. The process begins at A) when a new soft shell (fine line) grows beneath the hard outer shell (heavy line).

Prawns and shrimps

Prawns and shrimps are names that are often used interchangeably. However, there are two commercially important groups, penaeids and carideans (Figure 7.4).

Most penaeid prawns (called shrimps in some countries such as the USA) produce juveniles that require brackish water nursery areas in which to grow. Hence, prawns are usually found only in areas that have sufficient rainfall to produce rivers and estuaries. In western Pacific islands, prawns are found from Papua New Guinea to Tonga.

The giant tiger prawn shown in Figure 7.4 is one of the most commonly farmed species. Juveniles are either collected from nearby inshore areas or bred in a hatchery, before being placed in shallow water ponds to grow.

Caridean shrimps are much more widely distributed than penaeids and various species are found from high mountain pools to the depths of the ocean. Freshwater shrimps belonging to the genus *Macrobrachium* are found in rivers in many Pacific Islands. Deepwater caridean shrimps have been found in trapping surveys off many Pacific Islands in depths of 600 to 800 m. However, catching shrimps in such depths has not been viable economically.

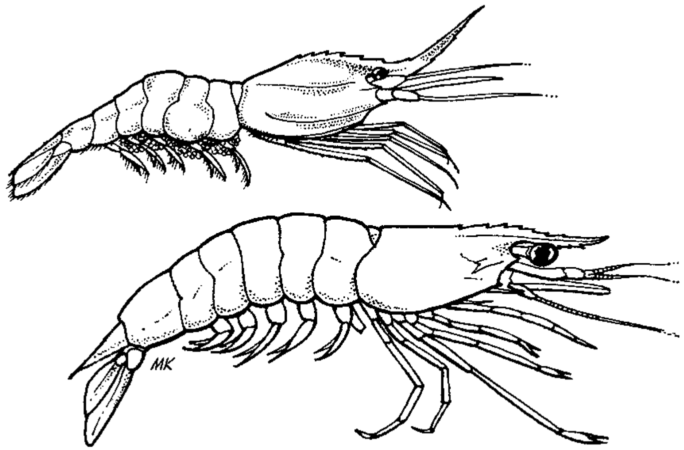


Figure 7.4: Shrimps and prawns. From the top, the caridean deepwater shrimp, *Heterocarpus laevigatus* and, the giant tiger prawn, *Penaeus monodon*.

Lobsters and slipper lobsters

Tropical spiny lobsters (family Palinuridae), including the striking painted lobster shown in Figure 7.5, are widely distributed in the Pacific. Some species are taken by divers on the exposed sides of coral reefs down to a depth of 10 m. During the night, and at particular phases of the moon, some species forage over the reef tops where they are caught by groups fishing with lights and spears.

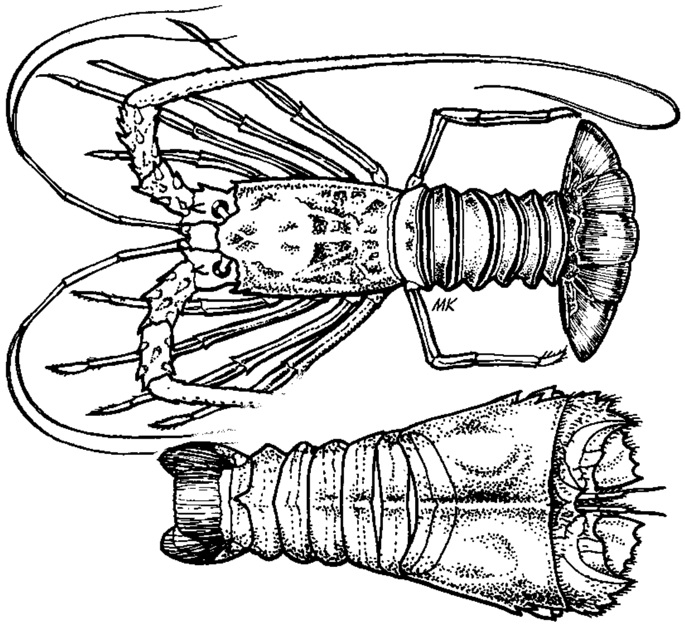


Figure 7.5: Clawless lobsters; from the top the spiny (or painted) lobster, *Panulirus versicolor*, and the slipper lobster, *Thenus orientalis*.

Most species of spiny lobsters are protected by fisheries regulations – in some areas fishers can only take a limited number (a bag limit or quota) and have to return "berried" females (those carrying eggs) to the sea. Collecting spiny lobsters using SCUBA gear is too easy, and some countries have banned its use in the interests of conservation.

Related to spiny lobsters are the strange squashed-looking crustaceans generally called slipper lobsters, shovel-nosed lobsters, or simply bugs (Figure 7.5). Their common names come from their flattened appearance and their broad antennae.

Also related to prawns and lobsters are the ghost shrimps, marine yabbies and mud lobsters (Figure 7.6). The small pale cream or pink ghost shrimps live in burrows in silty sand. The greenish brown mud lobster makes elaborate and multi-chamber burrows in silty and muddy areas, particularly among mangroves at the mouths of estuaries.

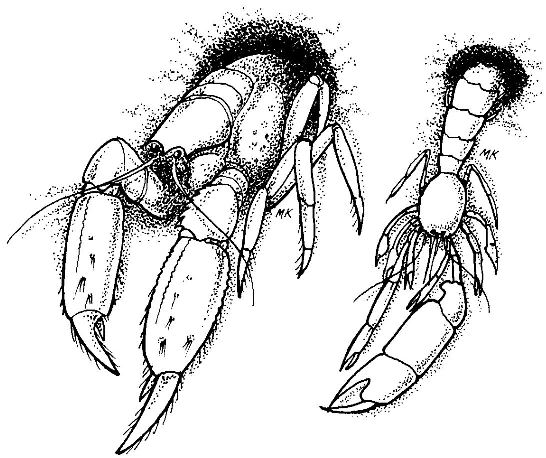


Figure 7.6: Burrowing lobsters. From the left, the mud or mangrove lobster, *Thalassina,* (16 cm) and the ghost shrimp or marine yabby, *Callianassa,* (8 cm).

In Fiji, fishers set an ingenious trap at the entrance of a mud lobster's burrow. A springy mangrove root, tied to a small noose set at the burrow's entrance, is bent over and held down by a trigger. When the mud lobster moves through the noose the trigger is tripped and the spring jerks the mud lobster off the ground.

Crabs

With approximately 4500 species, crabs are the most successful of all large crustaceans. Some hide in burrows and some in seashells, and others have moved onto the land.

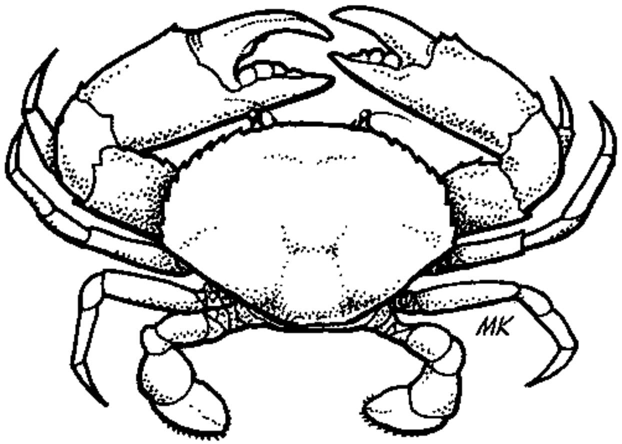


Figure 7.7: The mangrove or mud crab, *Scylla serrata* (24 cm carapace width).

A few species, such as the large mangrove crab, have become adapted for swimming with flat paddles at the end of the last pair of legs. The mangrove crab burrows in silty areas in estuaries and inlets. It is caught in baited traps and tangle nets set in hoops on the sea floor in many Pacific islands.

Several species of crabs seem more associated with the shoreline than the sea, and the most familiar of these are the soldier crabs, fiddler crabs and ghost crabs. On some sand flats, platoons of small soldier crabs move around to feed on detritus left by the tide.

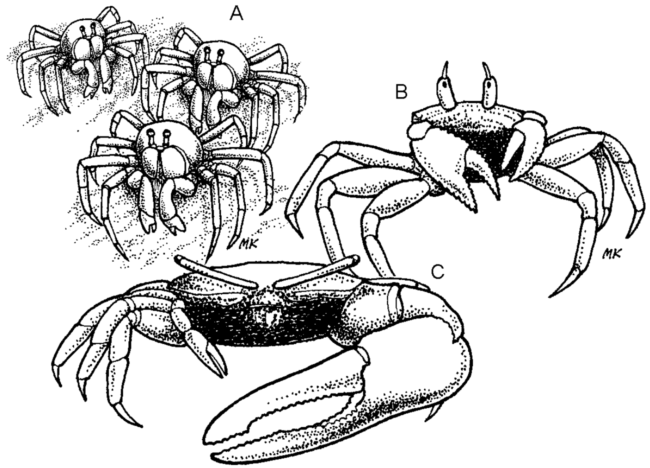


Figure 7.8: Tropical shoreline crabs
A) soldier crabs, *Mictyris* (20 mm),
B) stalk-eyed ghost crab, *Ocypode* (35 mm), and
C) fiddler crab, *Uca* (35 mm).

A very strange crab

An ancient group of burrowing crabs includes the spanner or frog crab, *Ranina ranina,* which takes its name from the spanner-like shape of its claws. The species, which grows to a weight of about 1 kg, is believed to be present in deeper water from Africa across the Indo-Pacific to Hawaii. The species is the basis of commercial trap fisheries in Hawaii (where it is known as the Kona crab) and in northeastern Australia.

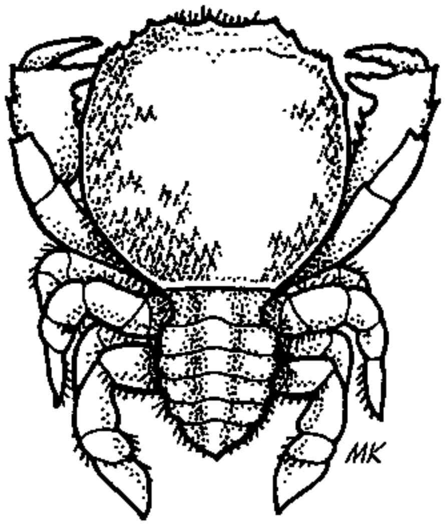


Figure 7.9: The spanner crab, frog crab, or kona crab, *Ranina ranina* (20 cm shell length)

Hermit crabs and stone crabs

The bodies of most hermit crabs fit within the empty seashells. The crabs appear never to kill the original occupants of the shells, and seek progressively larger empty shells as they grow. In some species, the larger of their two claws is used as a tightly fitting trapdoor to the shell in which they live (Figure 7.10).

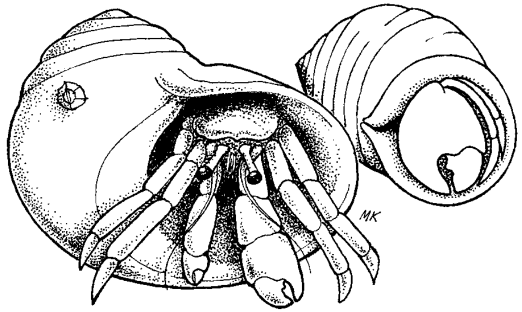


Figure 7.10: Hermit crabs. At left, *Coenobita variabilis.* At right, the smaller hermit crab, *Coenobita rugosa,* is shown with its larger claw being used as a trapdoor.

Two other relatives of the hermit crabs have evolved away from a total dependence on molluscan shells – these are the stone crabs and the coconut crabs. The king crab, which is the most common source of canned and frozen crabmeat, is the best-known example of a stone crab. And its relative, the large coconut or robber crab was once widespread on Pacific Islands.

Coconut crabs live on land and only the juveniles are housed within shells like their hermit crab relatives. They possess massive crushing claws, and long legs that enable them to climb trees. It believed that these crabs can crush growing coconuts with their huge claws. However, large adults are certainly capable of using their claws to husk the shell of a coconut.

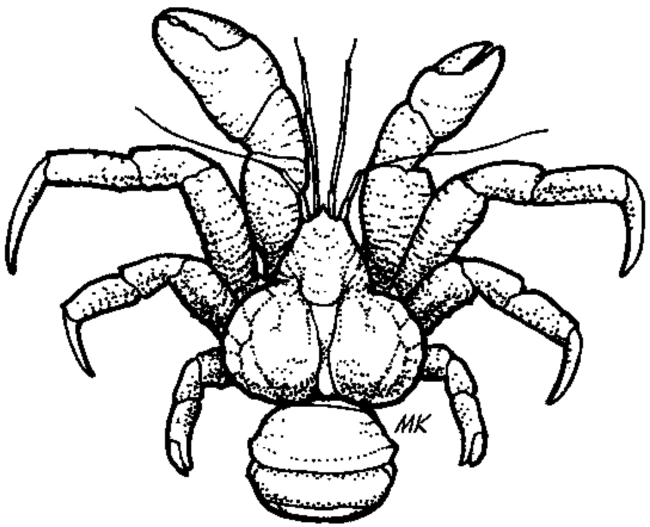


Figure 7.11: The coconut, or robber, crab, *Birgus latro,* which grows to a weight of 4 kg.

The coconut crab was once distributed widely in the tropical Indo-Pacific but it has now all but disappeared on continents. The docile crab is easily caught and contains flesh that is sought after by humans, dogs and pigs alike. It seems that wherever humans and their domestic animals have settled, the coconut crab has disappeared. In some Pacific Islands such as Vanuatu there have been attempts to provide refuges for breeding populations.

Toxic crabs

Not quite all crabs are edible. The large and eye-catching toxic reef crab, *Zosimus,* with its brown or red pattern of blotches on a pale cream background is sometimes common on coral reefs in the Pacific. The flesh of this meaty crab, even when cooked, is toxic, and can result in severe sickness and even death.

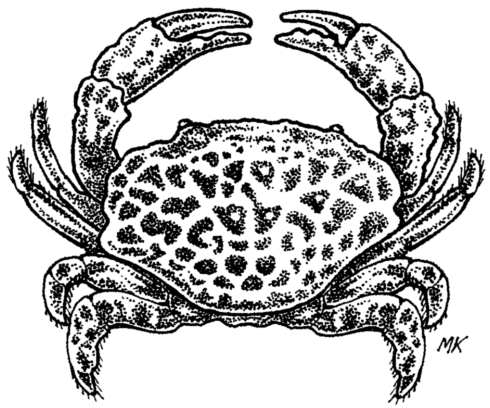


Figure 7.12: The toxic reef cab, *Zosimus aenus.*

8. Molluscs - clams to octopuses

There are over 65 000 species of molluscs, including creatures as different as the trochus, giant clam and octopus (Figure 8.1). In many molluscs the soft parts are covered by one or two shells. With the exception of the bivalves (cockles and clams), all molluscs have teeth arranged in rows along a file-like flexible strip called the radula that is used in feeding.

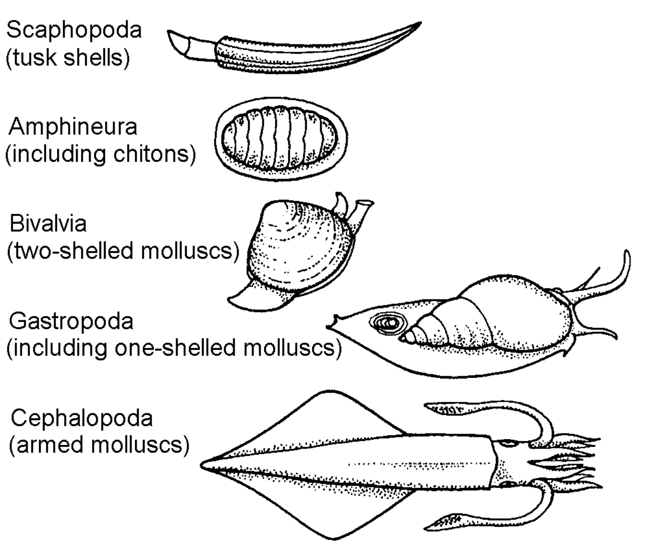


Figure 8.1: The five classes of molluscs.

Clams, oysters and mussels (bivalves)

Bivalve molluscs have two shells, or valves, joined together by a horny ligament called the hinge. The two shells are held closed by one or two adductor muscles (that have to be cut by a knife when opening cockles, clams and oysters). Under the shell, sheet-like tissue called the mantle seals the animal within, and contains glands that secrete new shell material.

Clams and other bivalve molluscs feed by pumping large quantities of seawater through their systems each day. Burrowing species have two tube-like siphons – water is drawn in one and expelled though the other. In clams, which filter out microscopic plant cells suspended in the water body, the inlet siphon is often flush with the sea floor. In clams that suck up organic deposits, the inlet siphon roves over the surrounding area like a vacuum cleaner (Figure 8.2).

Most cockles and clams have separate sexes. A female releases her eggs into the sea, and a male, perhaps some distance away, does the same with sperm. In common with most marine animals, millions of eggs may be released to increase the chances of sperm meeting egg in the sea.

After fertilisation, eggs hatch to small larval stages, which may drift in the sea for a week or so before settling on the sea floor to grow into adults. Some cockles and clams that are common in the Pacific are shown in Figure 8.3.

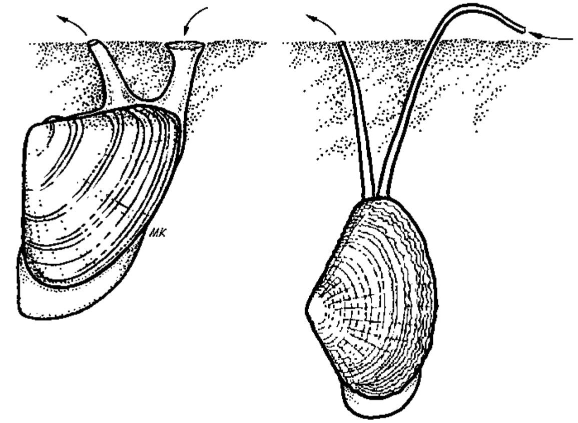


Figure 8.2: At left, a suspension-feeding surf clam, *Donax,* and at right, a deposit-feeding tellinid clam, *Quidnipagus.* Each clam has its foot and two siphons extended. Arrows show the direction of water flow.

Some bivalve molluscs live attached to hard surfaces and a few species even swim through the water for short distances. Perhaps the most familiar of the swimming molluscs are the scallops (shown previously in Figure 6.1), which appear to eat their way through the water with their shells.

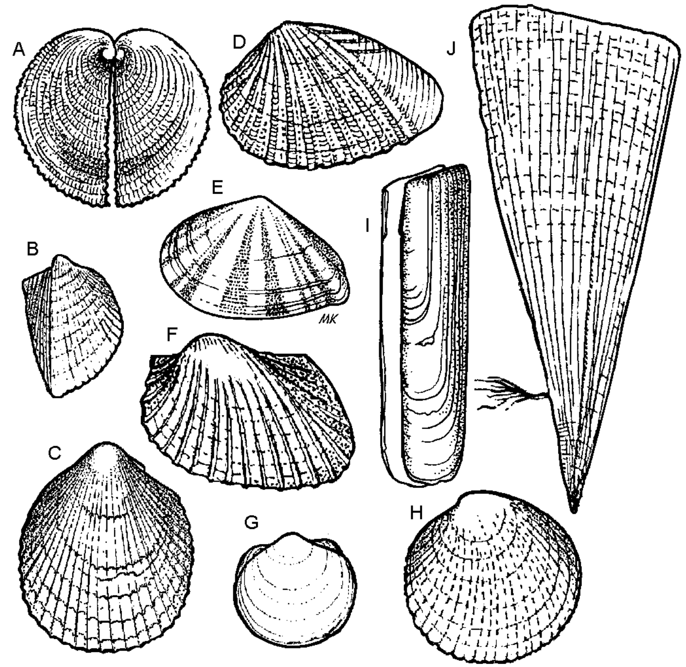


Figure 8.3: Pacific cockles and clams.
A) heart cockle, *Corculum,*
B) half-heart cockles, *Hemicardium, Fragum*,
C) coconut-scraper cockle, *Vasticardium*
D) tropical venus clams, *Gafrarium,*
E) tellins or sunset shells, *Tellina, Quidnipagus*
F) ark shells, *Arca, Anadara,* G) buttercup lucine, *Anodontia*
H) tiger lucine, *Codakia,* I) jacknife clams, *Solen, Ensis*
and J) pen or fan shells, *Pinna, Atrina*
Sizes range from 4 cm in the half-heart cockle
to 25 cm in the pen shell

Some molluscs have a special gland called the byssus that can produce either adhesive fluid or special threads for attachment to hard surfaces. In oysters, thorny oysters, and jewel-box clams one shell becomes permanently cemented to the substrate. Mussels and carditas secrete a cluster of flexible threads to grip hard surfaces.

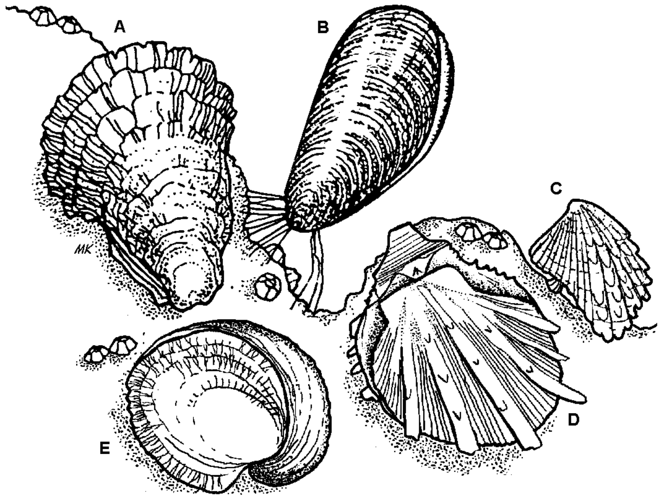


Figure 8.4: Bivalve molluscs that attach to hard surfaces. From top left and clockwise, A) Pacific oyster, *Crassostrea gigas,* B) mussel, *Mytilus,* C) cardita, *Cardita,* D) thorny oyster, *Spondylus,* and E) jewel box clam, *Chama.*

Because they do not move and can filter out their food from passing water currents, oysters and mussels are low-cost candidates for aquaculture. The Pacific oyster is now one of the most widely distributed of all farmed marine organisms. Although transplantations to new areas have provided considerable benefits, the introduction of species is not without risk. Besides the possibility of introducing parasites and disease, there is a risk that the introduced species will outcompete local or endemic species for settling space, and eventually displace them.

The black-lip pearl oyster (Figure 8.5), which produces grey to black coloured pearls, is farmed in Japan and the Philippines as well as in Pacific island countries such as French Polynesia and the Cook Islands.

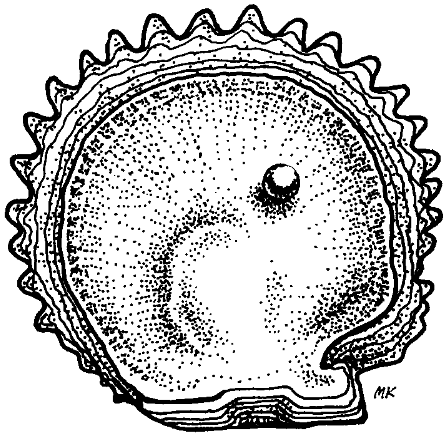


Figure 8.5: The blacklip pearl oyster, *Pinctada margaritifera.*

Cultured pearls are produced by deliberately "seeding" a pearl oyster with an irritant around which a pearl may form. The shells are wedged apart to allow the implantation of a small piece of mantle tissue and a shell fragment nucleus into the gonad. The mantle tissue grows around the nucleus, and deposits an increasing number of layers of shell until a pearl is formed (Figures 8.6).

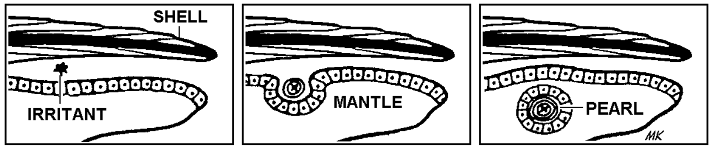


Figure 8.6: The sequence of pearl formation.

The largest and most spectacular of all the two-shelled molluscs are the giant clams (Figure 8.7) found in the tropical Indo-Pacific, where they are highly regarded as food by coastal communities.

Only eight species of giant clams are known, and the largest of these grows to weights of over 250 kg and may live for over 100 years. Large clams are the stuff of legends, and divers drowning with their legs trapped between the shells have featured in adventure stories and movies. In fact, although the muscles of a giant clam can hold its shells shut against tremendous leverage, they are too weak to close rapidly and trap an arm or leg.

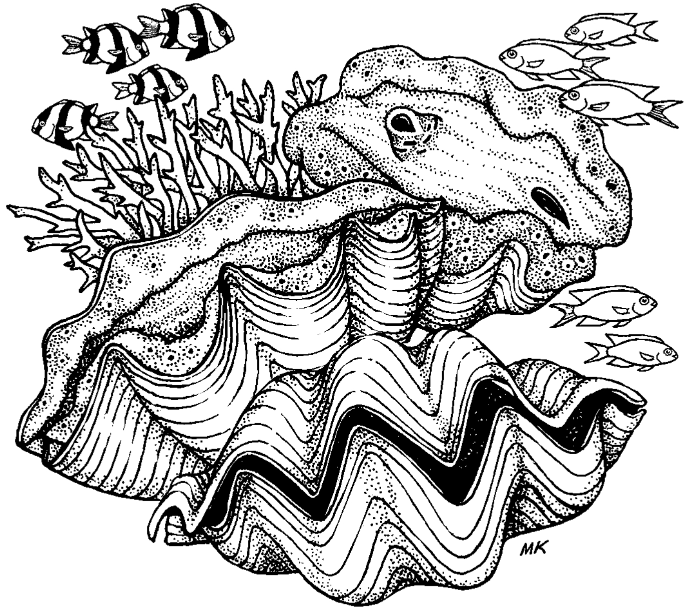


Figure 8.7: The largest of all giant clams, *Tridacna gigas.* The shells of the clam at the top of the figure are open, revealing the fleshy mantle and two siphons – water enters the right-hand siphon and is expelled through the left-hand one.

Giant clams have a relationship with microscopic plant cells called zooxanthellae that live in the tissues of their mantles – the fleshy and sometimes brightly coloured part that is exposed when the shells gape open. This is an example of symbiosis (discussed in relation to corals in Section 4).

The algal cells gain food (from the waste products of the clam) and the giant clam gains oxygen and carbohydrates produced by photosynthesis. Because of their reliance on symbiotic algae, giant clams require sunlight and are found only in clear, shallow water. And, in such locations, they can easily be seen and collected by human predators. Giant clams have been heavily fished in many islands and some species are locally extinct in Melanesia and Micronesia.

However, several Pacific island countries are farming giant clams. Clams held in tanks are induced to produce eggs, which are then fertilised with sperm from a different clam. And after a month or so, the resulting small clams can be placed in suitable growing areas, often in shallow lagoons. Several Pacific Island countries are breeding giant clams to restock depleted areas of reef and some are producing small clams for sale on the overseas aquarium market. Because of their symbiotic relationship with plant cells, giant clams are unique in being the only farmed marine animals that can feed from sunlight.

All of the cockles and clams described above are found in shallow water and are easily collected as human food. Many different species are harvested from a range of inshore habitats including estuaries, mud flats, sandy beaches and lagoons. Clams and cockles are an important source of food in bad weather when fishing offshore is not possible.

Trouble in two shells

Bivalve molluscs feed by pumping large quantities of seawater containing microscopic plants and other organic material through their systems each day. In doing this they also collect bacteria from the water. *Vibrio* bacteria, which are common in coastal areas, are easily destroyed by cooking but may cause seafood poisoning in people eating raw shellfish.

In areas of large populations, particularly if sewerage systems are unreliable, it is reasonable to assume that seawater contains many nutrients and therefore more than its share of bacteria.

Sea snails (gastropods)

Most sea snails or gastropods have a single shell that grows in a series of successively larger whorls around a central axis, and terminates at an opening. The head often has tentacles and eyes, and a muscular foot, on which many gastropods crawl or glide across the sea floor. In some species, the foot has a trap-door-like disk, called the operculum, on the upper surface. As the foot is retracted into the shell, the operculum forms a protective door to the shell opening. The spiral-patterned operculum (sometimes called a “cats eye”) of a turban shell is shown in Figure 8.8B.

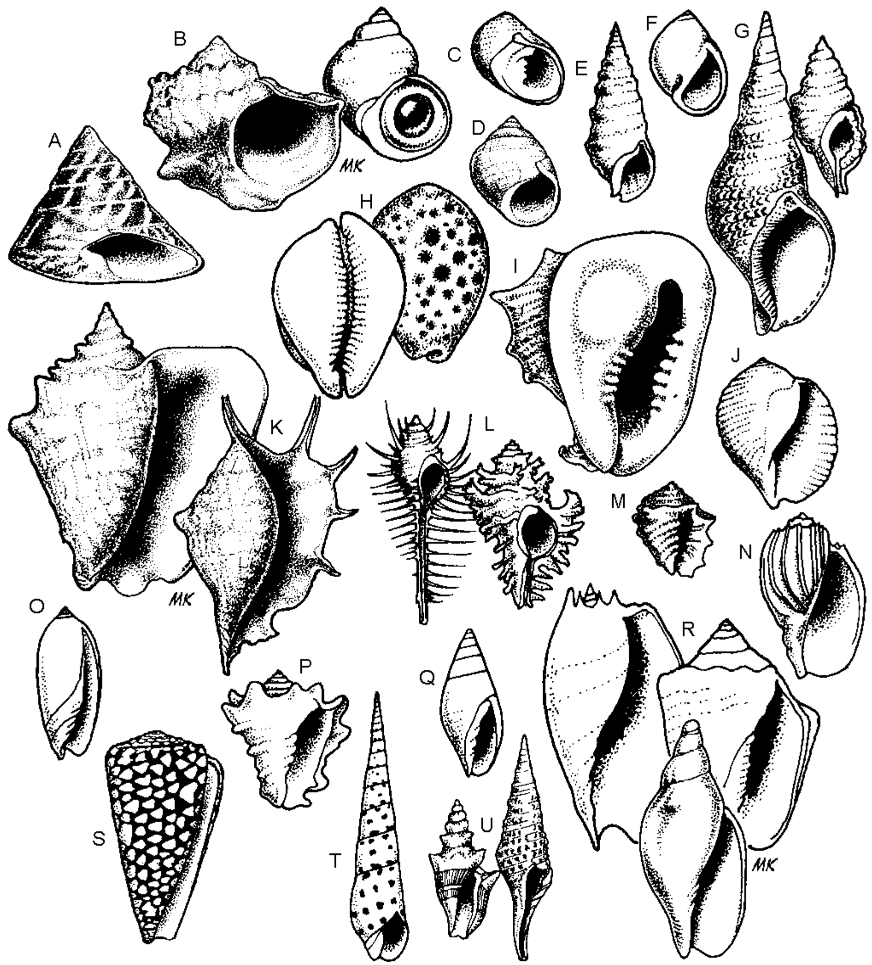


Figure 8.8: Sea snails (gastropods). Common names, family names and indicative sizes (in cm) are given.

A) top shells, Trochidae (2-14),
B) turbans, pheasants, Turbinidae (3-20),
C) nerites, Neritidae (1-5),
D) periwinkles, Littorinidae (3-5),
E) ceriths, Cerithiidae (2-10),
F) moon or necklace shells, Naticidae (2-10),
G) tritons, Cymatiidae, Ranellidae (1-40),
H) cowries, Cypraeidae (2-10),
I) helmets, Cassidae (6-25),
J) tun shells, Tonnidae (8-15),
K) conchs, spider shells, Strombidae (5-35),
L) murexes, Muricidae (5-18),
M) rock shells, drupes, Thaididae (2-12 cm),
N) harp shells, Harpidae (5-10),
O) olives, Olividae (4-10),
P) vase shells, Vasidae (5-12),
Q) mitres, Mitridae (1-10 cm),
R) volutes, balers, Volutidae (2-25),
S) cones, Conidae (3-20),
T) augers, Terebridae (3-25),
U) turrids, Turridae (2-12)

Most gastropods have separate males and females although a few species can change sexes. Males deposit sperm in females, and the fertilised eggs are released either in gelatinous strings, cases, or capsules. Some of the egg cases are bizarre - the spiral collar of sand found on ocean beaches, for example, is the egg case of the moon snail (see Figure 8.11 in this Section).

Many of the larger gastropod molluscs shown in Figure 8.8 are used as food. And a much wider range of species is exploited just for their shells. Shells have been used as ornaments on tombs in the Egyptian pyramids and are used today as personal ornaments in many cultures including those of Pacific islands. A shell necklace from the Pacific is shown in Figure 8.9.

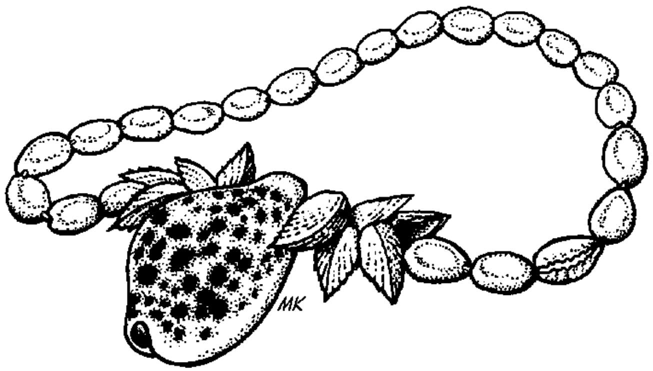


Figure 8.9: A Pacific Island necklace of small golden ring cowries with a single central tiger cowry flanked by cockle shells.

Several molluscs with shells that have a pearly inner layer, such as the green snail and the pearl oyster (Figure 8.5), are used in making fishing lures and in ornamentation. Top shells are collected for their meat and their shells are used in the manufacture of buttons for the clothing trade (Figure 8.10).

Pearl buttons

The top shell, *Trochus niloticus,* is collected in some islands for use in the manufacture of buttons for European and Asian markets. Holes are drilled around the spiral shell to produce the circular pieces of shell, which are polished to make the buttons.

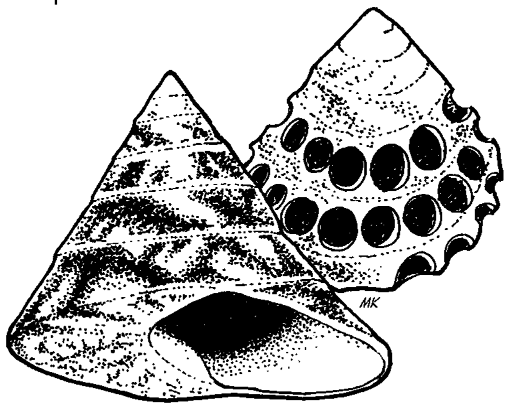


Figure 8.10: Two top shells, *Trochus niloticus*, one of which has been drilled to remove the circular pieces of shell used to make buttons.

All gastropod molluscs have remarkable teeth called radula. Herbivorous species, such as trochus, use their radula to graze algae. Carnivorous species use their radula to drill holes in and even harpoon their prey. The moon snail (Figure 8.11) drills a beveled hole in the shells of small clams and uses its extendable mouth to dissolve and suck up its victim's flesh.

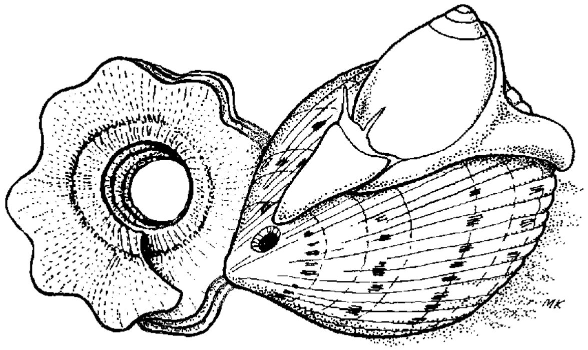


Figure 8.11: The moon snail, *Polinices,* on a cockle; the beveled hole drilled by the snail is shown on the left-hand side of the cockle. The moon snail's flat spiral egg case, made of sand and mucus is shown at left.

In some gastropods the radula have evolved into more formidable weapons. In cone shells the radula teeth are arranged as a harpoon with grooved barbs that can inject toxic saliva into its live prey. Smaller cones hunt polychaete worms, but the larger ones can kill small fish (Figure 8.12).

Cone shells - beautiful but dangerous

A cone has a tube-like snout or proboscis that fires small harpoons. In some species the harpoon, which contains an extremely potent venom, can penetrate clothing and skin. Holding the cone by the wide end is less dangerous but the proboscis, which emerges from the narrow tapered end, can extend for some distance.

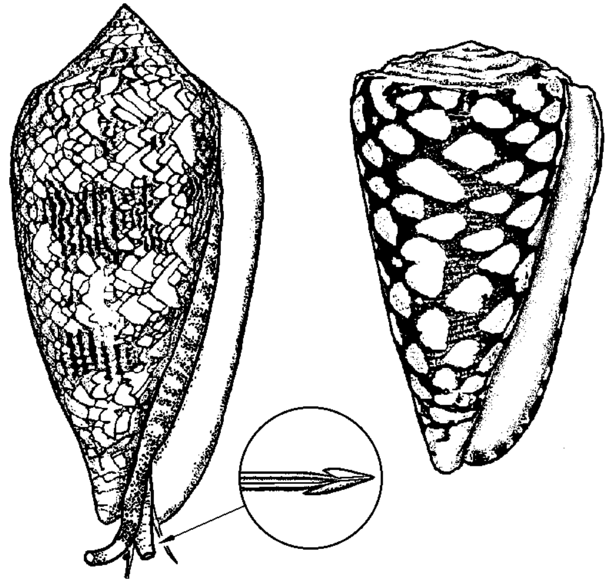


Figure 8.12: Cone shells dangerous to humans. The textile cone, *Conus textile,* (left) and the marbled cone, *Conus marmoreus.* Sizes up to 13 cm. The inset shows a close-up of a poisonous dart contained within the proboscis (arrowed).

There are over 400 different species of cone shells, and many are highly prized by shell collectors.

The particularly striking cone known as the glory-of-the-seas, *Conus gloriamaris,* is reported to be the most valuable shell in the world. This cone looks superficially similar to the common textile cone shown in Figure 8.12 but has a much finer network of colouration. Only 70 or so specimens have ever been found and perfect specimens have sold for US$1,200!

Octopuses and their relatives (Cephalopods)

There is one other group of highly advanced molluscs, in which most of its members have escaped from a reliance on the sea floor. This group of molluscs, the cephalopods, includes the octopus, squid and cuttlefish.

Only the octopus is associated with the sea floor. It lives in crevices in rocks and coral reefs from which it emerges to attack its prey. The octopus has eight sucker-bearing arms attached to a saclike body and uses jet propulsion to move through the water. If caught out in the open, an octopus will force water through its funnel (shown below the eyes in Figure 8.13) and swim off through the water at a speed surprising for an animal that lives on the sea floor.

The stories of divers wrestling with killer octopuses are the stuff of fiction, and most octopuses are harmless to humans. Its suckers can leave ring-like marks on human skin, and all octopuses have a parrot-like beak that can give a small bite, but that is about all. However, there is octopus whose bite is extremely toxic - this is the small blue-ringed octopus that is found in southern waters of Australia.

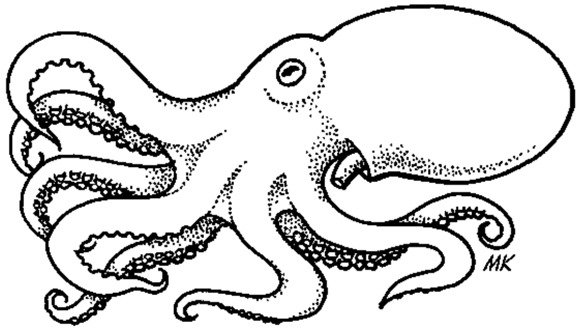


Figure 8.13: The octopus, *Octopus vulgaris.*
The funnel extends from the mantle below the head.

Squids and cuttlefish (Figure 8.14) have evolved for a pelagic existence in the open ocean and, squids in particular, are like jet-propelled rockets. Their mantles are often extended into two stabilizing fins, and the shells are reduced to very light internal structures. Squids have transparent "pens" and cuttlefish have calcified "cuttlebones" of light cellular material that aids in buoyancy.

Squids and cuttlefish have ten tentacles - eight smaller ones and two longer ones. Like the octopus, they possess a pair of beak-like jaws to hold prey and teeth (radula) that are used to rasp at flesh. And, like octopuses, they release ink to escape from their enemies. Nobody is sure whether the would-be predator just cannot find the cephalopod in the ink, or is frightened off by a black cloud that gives the impression of a much larger animal.

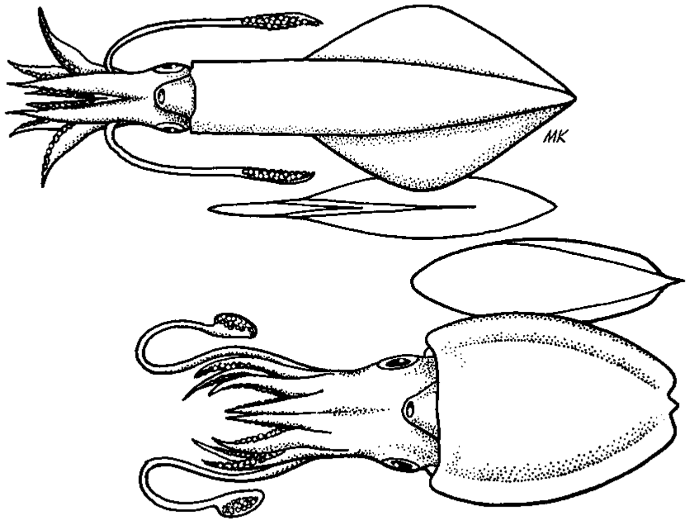


Figure 8.14: A squid, *Loligo,* (top) and a cuttlefish, *Sepia,* (below). The internal shells of each, the pen of the squid and the cuttlebone of the cuttlefish, are shown in the background.

Unlike most cephalopods, the pearly or chambered nautilus has an external shell (Figure 8.15). It has large cat-like eyes and many slender arms without suckers. The shell is rounded to withstand the pressure at the great depths in which it lives and is divided into separate chambers, just as a ship is divided by watertight bulkheads. In the Middle Ages, when small numbers of nautilus shells were obtained by travelers in the East Indies, the shells were regarded as great treasures.

The nautilus is, in fact, a living fossil and its relatives were swimming in ancient seas about 50 million years before the first primitive fish appeared. Its distribution is now restricted to tropical waters of the eastern Indian Ocean and the western Pacific Ocean.

Figure 8.15: The chambered or pearly nautilus, *Nautilus* (18 cm). The broken shell at right shows the chambers inside the shell.

9. Echinoderms - sea cucumbers to sand dollars

Approximately 5300 species of animals commonly called sea lillies, sea stars, sea cucumbers and sea urchins are echinoderms (meaning "spiny-skinned").

Echinoderms are exclusively marine, and have a skeleton of bony plates. The skeleton is in the form of an enveloping shell or test of interlocking plates in sea urchins, and is reduced to small spikes or spicules embedded in a thick body wall in sea cucumbers.

The most distinctive feature of echinoderms is the water-vascular system - an internal system of water filled tubes from which blind-ended sacs, called tube feet, project through the body wall. Echinoderms have separate sexes, and eggs are fertilised externally before developing into planktonic larvae.

Sea cucumbers

On the sea floor, sea cucumbers haul their plump sausage-shaped bodies across the sand using rows of tube feet on their undersides. In shallow lagoons, cucumbers play an important role in clearing the sand of debris. A sea cucumber bulldozes its way along taking in sand through its tentacled mouth and digesting any organic material.

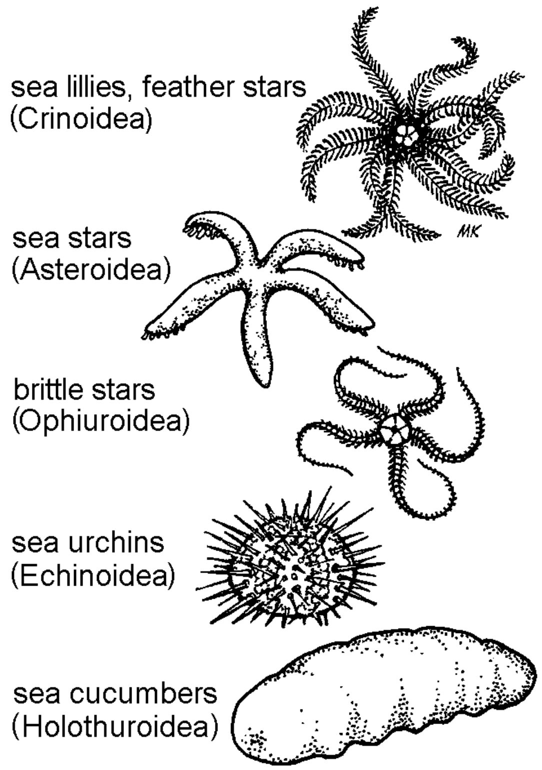


Figure 9.1: The five classes of echinoderms.

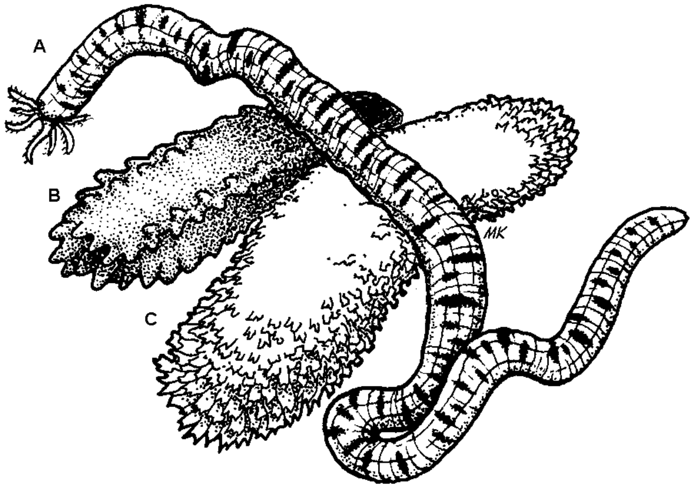


Figure 9.2: Holothurians or sea cucumbers.
A) the snake-like *Synapta maculata* (over 3 metres)
B) the dark green cucumber, *Stichopus chloronotus* (35 cm),
C) the prickly red sea cucumber, *Thelenota ananas* (50 cm).

When under attack, some sea cucumbers cast out their intestines, leaving them for the attacker. The sea cucumber is then able to regenerate its tissues and organs. Other species throw out sticky white threads from their anus to entangle their enemies.

Several species of sea cucumbers are collected and processed by boiling and drying to become beche-de-mer or trepang for export to markets in Southeast Asia.

In several Pacific Islands, including Palau, Pohnpei, Samoa, Tonga and the Cook Islands, sea cucumber guts and gonads are eaten raw or partially fermented in seawater. A small hole or slit is made in the sea cucumber from which the internal organs are removed. The animal is then returned to the sea where it is believed to regenerate its internal organs.

Sea stars

Sea stars have radial symmetry often with five, but sometimes more, arms radiating out from a central disc bearing a mouth on the lower side.

Colours and shapes of sea stars vary greatly (Figure 9.3). The horned sea star has arms decorated with blunt bright red horns, and the large pincushion star is so globular that it has virtually no arms at all.

Sea stars also vary greatly in their diet. The sand sea star feeds on detritus. The horned sea star and the pincushion star suck polyps from hard corals.

Some sea stars are hunters of clams, cockles, oysters and mussels. The sea star uses the tube feet on its arms to grip the two shells of the mollusc. Over many hours, the sea star exerts a small but relentless pressure until the clam’s muscles weaken and its shells gape open.

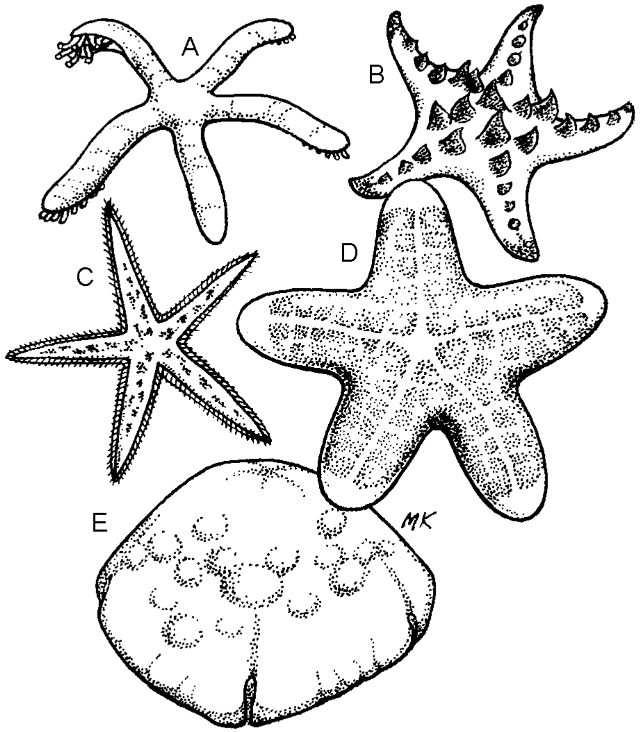


Figure 9.3: Pacific seastars.
A) the blue seastar, *Linckia laevigata* (25 cm)
B) the horned seastar, *Protoreaster nodosus* (25 cm)
C) the sand seastar, *Archaster* (15 cm)
D) the blunt-armed seastar, *Choreaster granulatus* (30 cm)
E) the pin-cushion star, *Culcita novaeguineae* (25 cm).

Sea stars have a remarkable ability to survive being cut up, squashed, and bitten in two. Oyster farmers used to collect predatory sea stars from their oyster beds and grind them up before throwing the pieces back in the sea. But each individual piece (as long as it was attached to a small part of the central disc) is capable of growing into a new sea star.

Sea urchins, sand dollars and heart urchins

Sea urchins have globular bodies and sand dollars have flattened bodies. Heart urchins have elongate bodies and bristle-like spines ending in paddles that are adapted for burrowing into the sand. The dried tests of all three types have rows of perforations through which, in life, the characteristic tube feet extend (Figure 9.4).

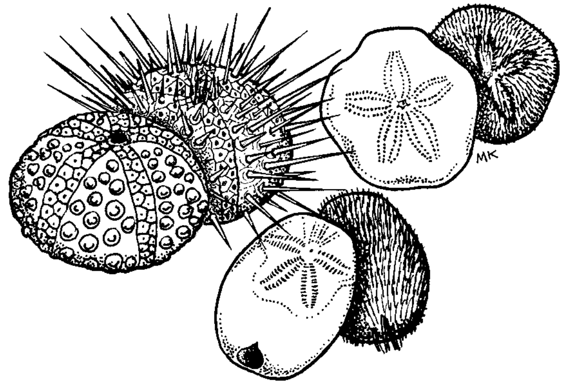


Figure 9.4: From the left, a sea urchin, sand dollar and heart urchin. The living animals are shown with their empty shells, or tests, in the foreground.

Injuries from stepping on sea urchins are common. The spines are covered with a thin layer of tissue that rots and sends the surrounding human skin septic. But there are some sea urchins that are more dangerous. The hatpin urchin (Figure 9.5) has needle-like spines over 30 cm in length and these contain toxins capable of inflicting a painful wound.

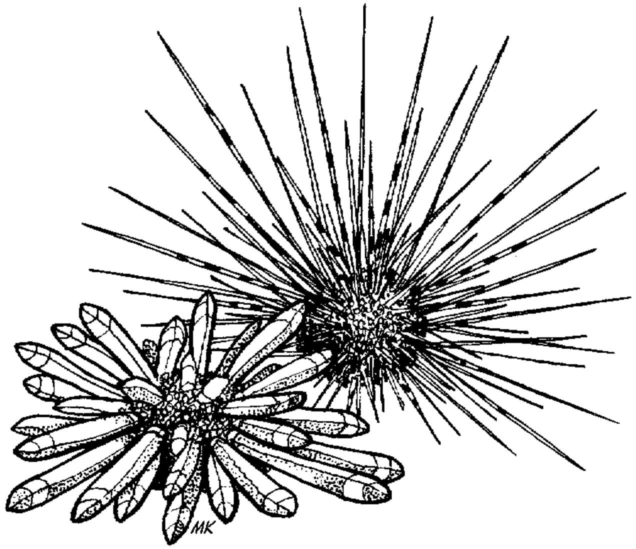


Figure 9.5: The slate-pencil urchin (left), *Heterocentrotus mammillatus* and the toxic hatpin urchin, *Diadema setosum*

Particular species of sea urchins have spines that are capable of rotating back and forth like a drill allowing the urchin to burrow into rock. Others, such as the slate-pencil urchin (Figure 9.5), have heavy, blunt spines designed to wedge the urchin in gaps and under boulders.

In spite of their hard tests and spines, urchins have several predators (Figure 9.6). And they are collected by humans in the shallow waters of lagoons. The roe of sea urchins is regarded as a delicacy in several countries, and small-scale fisheries are based on collecting species in temperate waters. In Japan, the roe, known as *uni,* is traditionally served draped on the sides of small wooden boxes and is consumed raw.

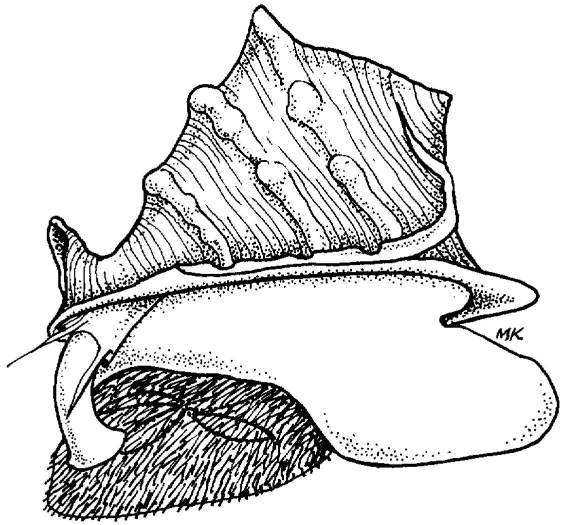


Figure 9.6: The helmet shell, *Cassis,* feeding on a heart urchin.

10. Fishes – butterflyfishes to tunas

Almost half of all species of animals with backbones, the vertebrates, are fishes. Fishes are distributed in environments from high mountain pools to the deepest parts of the ocean, and from the warm waters of coral reefs to the cold waters of Antarctica. Of the 12,000 or so species of marine fishes, as many of 7000 live on coral reefs and in nearby inshore habitats.

Fishes first appeared in the seas about 500 million years ago. These ancestral fishes were armored and heavy and were confined to the sea floor. In order to float fishes evolved along two separate lines, each of which solved the problem of buoyancy in different ways.

In one group, the sharks and rays, the heavy calcified skeleton was replaced by lighter cartilage. And the livers of sharks became huge and packed with light oil.

Sharks also maintain their position in the water column by have fixed pectoral fins that act as paravanes. As the shark moves forward through the water, pressure on the underside of the fins provides the same sort of uplift as on an airplane's wing, and this prevents the animal from sinking. Thus many, but not all, species of sharks have to swim continually to stay afloat.

The other group, the bony fishes solved the problem of being buoyant in a different way. The primitive lung used by ancient fishes living in shallow, de-oxygenated water evolved into the swim bladder of modern bony fishes that obtain oxygen through their gills. The lung of ancient fishes therefore became a gas-filled flotation organ in modern bony fish.

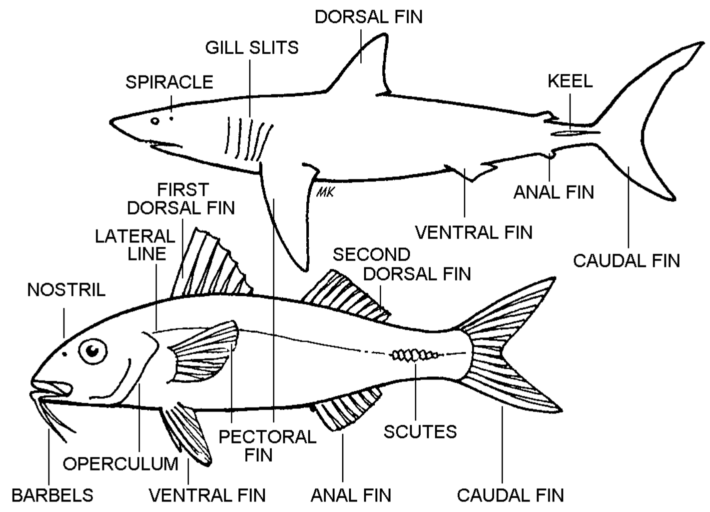


Figure 10.1: A shark and a bony fish, Features such as barbels and scutes occur only in some species.

The evolution of the swim bladder allowed bony fishes to move away from speed as a way of life. Pectoral fins, no longer required for aiding flotation as in sharks, could evolve to allow a greater range of movements and to live in a greater range of habitats. The ability to be bottom dwelling or surface swimmers, to live in caves or burrowed under the sand has allowed bony fishes to dominate the waters of the world.

Most fishes, about 96% of all species, reproduce simply by releasing eggs and sperm into the water. The fertilized eggs hatch to small larvae (usually about 5 mm in length) that usually drift with the plankton on ocean currents. The juveniles of many fish species grow in nursery areas, including reefs, banks, bays, and estuaries.

Inshore fishes

Many species of fish take advantage of the abundant food available in inshore areas (Figure 10.2).

Fishes such as mullets and ponyfishes have mouths that are extendable, and ideally suited for sucking up material in sediments. The lower jaws of goatfishes (or red mullets) have sensitive barbels with which to locate food in the bottom sediments. Garfishes have mouths that are directed upwards to scoop material including insects from the surface of the water.

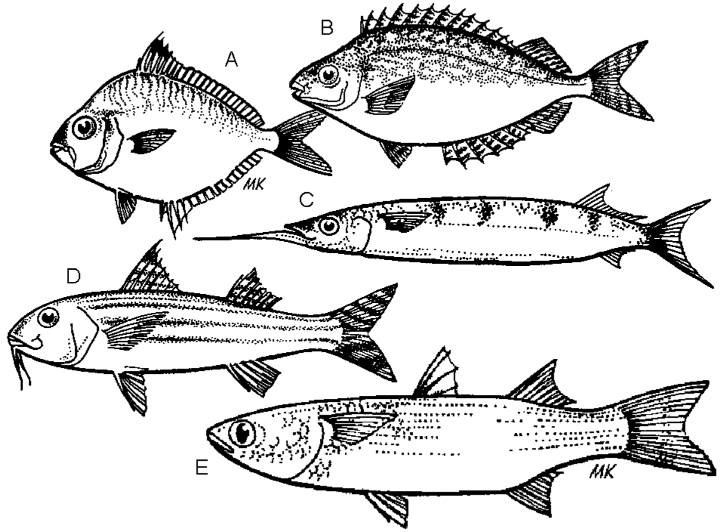


Figure 10.2: Fish families from sheltered inshore areas. A) ponyfishes (Leiognathidae), B) rabbitfishes (Siganidae), C) garfishes (Hemirhamphidae), D) goatfishes (Mullidae), and E) mullets (Mugilidae).

Coral reef fishes

Although there are thousand of different types of fishes on coral reefs, many of these belong to the relatively few families shown in Figure 10.3.

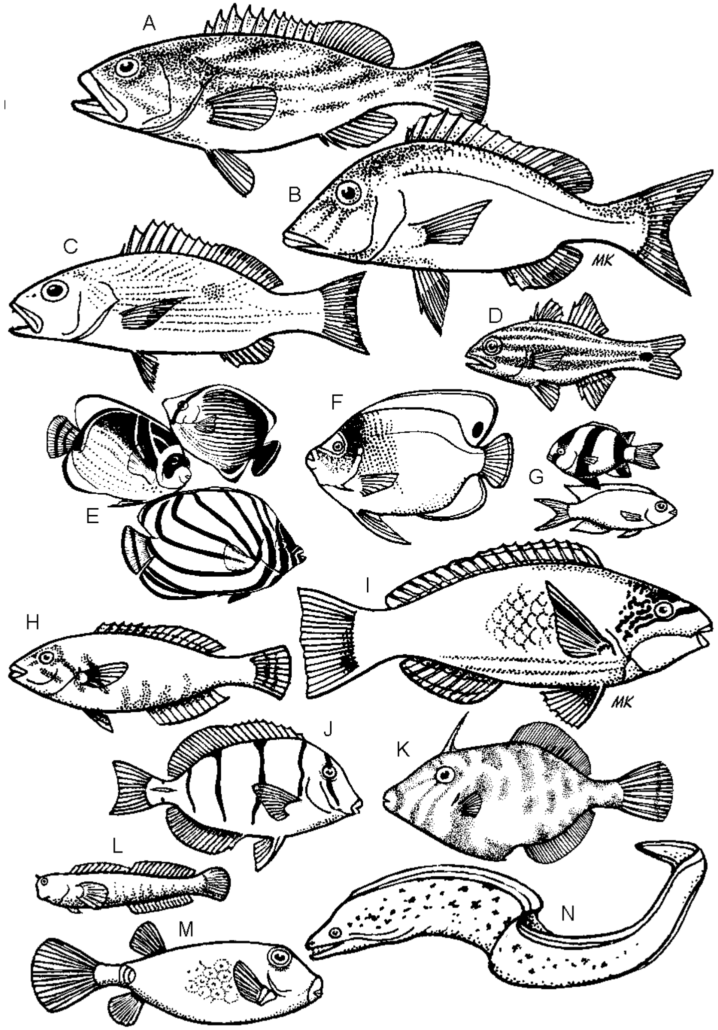


Figure 10.3: Common fish families on Pacific coral reefs.

From the top, examples include
A) groupers, coral cods and coral trouts (Serranidae)
B) emperors (family Lethrinidae),
C) snappers (Lutjanidae)
D) cardinalfishes, soldierfishes (Apogonidae)
E) butterflyfishes (Chaetodontidae),
F) angelfishes (Pomacanthidae)
G) damsels, humbugs, sergeants, anemone fishes (Pomacentridae)
H) wrasses (Labridae),
I) parrotfishes (Scaridae)
J) surgeonfishes (Acanthuridae),
K) triggerfishes (Balistidae)
L) gobies and blennies (Gobiidae and Blenniidae)
M) boxfishes and puffers (Ostraciidae and Tetraodontidae)
N) moray eels (Muraenidae)

The most conspicuous of the smaller reef fishes are often the many species of damselfishes that form large plankton-feeding schools above the corals. Some are opal colours of blue and green and the small humbugs have zebra stripes of black and white.

Butterfly fishes, renowned for their grace and vivid colour patterns, have pointed mouths to suck out polyps from live corals. Among the medium-size fishes, the parrotfishes may be seen feeding on the coral with their fused beak-like teeth.

Surgeonfishes move over large areas of reef feeding on fine mats of weed – these fishes have a sharp scalpel-like structure on each side of the tail base and should be handled with care.

When threatened, triggerfishes use their spines to jam themselves in crevices. Boxfishes have rigid box-like bodies and delicate fins that stick out of their hard casing like small inefficient paddles. The related puffers, toadfishes or blowfishes have flabby but inflatable bodies and are highly toxic (see later in Figure 10.8). Moray eels are common nocturnal feeders and live in reef crevices.

All of the fishes, even the small ones, shown in Figure 10.3, with the possible exception of gobies and blennies, are used as food by coastal communities.

Some of the most important food fishes in many Pacific islands, for example, are the various species of surgeonfishes. Even the tiny damselfishes may be caught and used to make soup. Unfortunately, the catching of small fish often involves surrounding small coral heads with a fine net and smashing the coral with a stick.

The larger and more mobile fishes of the reef include many different species of groupers, emperors and snappers. Other than small sharks, these fishes are the top predators on the coral reef and often move over large feeding ranges.

Beyond the coral reefs on the outer reef slopes, deeper water snappers and emperors (Figure 10.4) are caught in depths of about 200 metres off many tropical coasts. Because of their distance from coral reef ecosystems, these large species are believed to be unaffected by ciguatera (see Section 5).

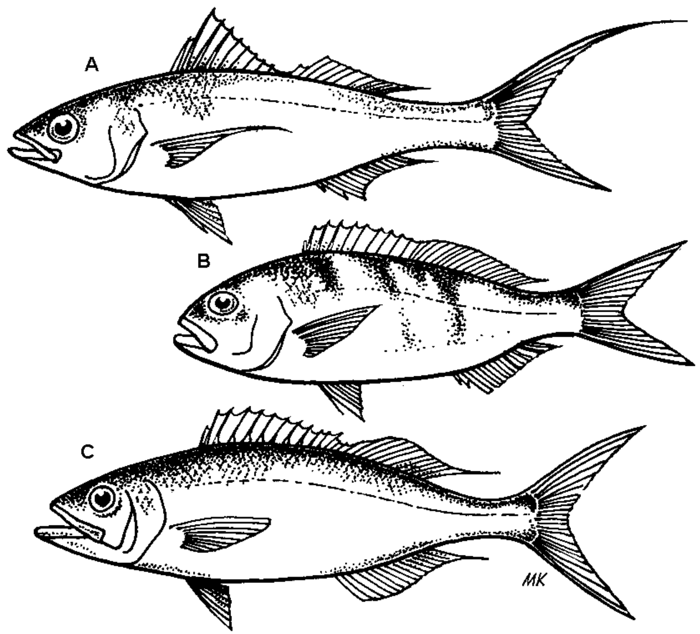


Figure 10.4: Tropical deepwater snappers.
A) *Etelis coruscans* (70 cm),
B) *Pristipomoides zonatus* (50 cm),
and C) *Aphareus rutilans* (80 cm).

Fish diets and heart disease

People that traditionally eat a lot of fish have relatively low rates of heart disease. Fishes contain nutrients called omega-3 fatty acids, types of polyunsaturated fats that seem to promote cardiovascular health. Since our bodies cannot manufacture their own supply of these fatty acids, we have to get them from the food we eat; mainly fish but also from such plants as flax, soybeans and walnuts. Omega-3-fatty acids are especially abundant in oily fishes such as sardines, mackerels, herrings and, to a lesser degree, tunas.

The increasing incidence of heart disease in people in Pacific Islands is likely to be related to the high consumption of imported low quality, fatty meats. Turkey tails, lamb ribs (lamb flaps) and canned corned beef are common items of diet in many Pacific Islands and these contain very high quantities of fat. The more traditional diet of fish provided protein with very little damaging fat and many health-giving nutrients.

Many coral reef fishes have vivid colours and bizarre markings. These may be used to advertise their particular feeding territories and intimidate their neighbours. Some brightly coloured fishes add aggressive displays, and even outright attack to their armory. The white-barred triggerfish (Figure 10.5) will defend its territory against much larger animals, and even rush in to nip human swimmers on coral reefs.

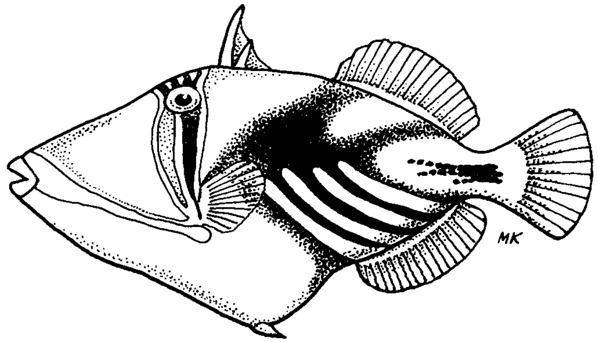


Figure 10.5: The white-barred triggerfish, *Rhinecanthus aculeatus.* This fish with its powder-blue body and diagonal white bars is aggressively territorial.

Some fishes have distinctive false “eye spots” near their tails or on other parts of their bodies – one such fish is the yellowmask angelfish shown in Figure 10.3F. Many predators rush in to attack the eye of their prey, perhaps to disable it more surely. If the attack is directed to a false eyespot, the prey has a chance to escape with a less damaging bite.

Cleaner fish make their living by cleaning the mouths and gills of larger fish. A large fish, such as a snapper, will wait at a “cleaning station” on the reef and open its mouth and expose its gills for the small cleaner fish to remove debris, dead skin and external parasites (Figure 10.6). The large fish will eventually make warning movements to encourage a cleaner fish to leave before it closes its jaws and moves away.

Many coral reef fishes mimic or imitate the colour and behaviour of other fishes. A palatable species may mimic the colours of a poisonous one to gain protection from predators.

A particular blenny mimics the colouration of the cleaner fish, and this similarity allows it approach large fish expecting to be cleaned. However, the sabre-toothed blenny rushes in to nip pieces from the skin and fins of the large fish (Figure 10.6).

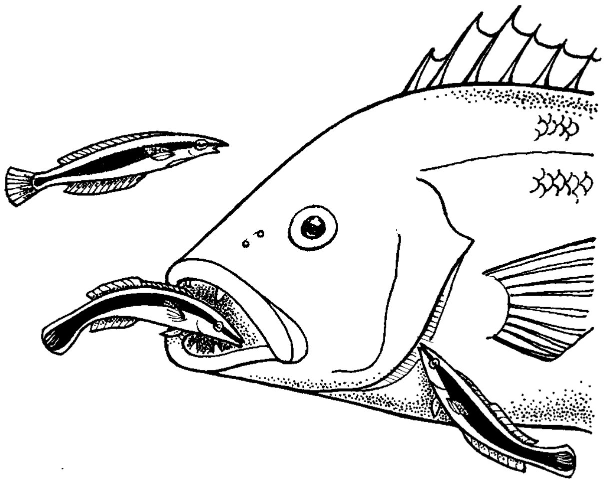


Figure 10.6: Blue and black striped cleaner wrasses, *Labroides dimidiatus,* cleaning the mouth and gills of a large snapper. Above left is the mimic, a parasitic sabre-toothed blenny, *Aspidonotus taeniatus.* Both fishes are about 8 cm in length.

Not all coral reef fishes have bright colours. Some fishes have evolved the opposite tactic of being inconspicuous. The poisonous stonefish, shown in Figure 10.7, is a master of camouflage. When motionless, its irregular projections and fins blend in well against a background of coral rubble, making it very difficult to see.

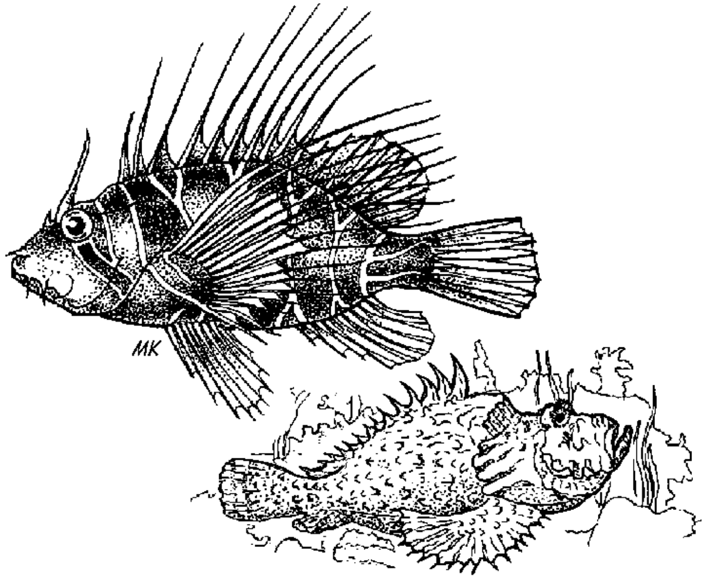


Figure 10.7: The lionfish, turkeyfish or firefish, *Pterois* (up to 28 cm) and the estuarine stonefish, *Synanceia horrida* (26 cm).

Stonefishes are not aggressive but are sometimes stepped on by people walking in shallow water near coral reefs or in estuaries. Their spines have glands that discharge venom into the wound.

The venom is a protein that is destroyed by heat and by both alkalis and acids - immersion of the affected part in hot water with vinegar or ammonia may help. If the victim is affected severely, medical aid should be sought as the effects can include shock, muscular paralysis and cardiac arrest. A member of the same family as stonefishes is the handsome but also venomous lionfish or firefish with its feathery extended fins.

Whereas some animals sting (are venomous) others are poisonous to eat (are toxic). Puffer fishes, toadfishes or blowfishes (Figure 10.8) are always toxic. These fish get their common names from their ability to inflate themselves by taking in large quantities of water or air.

The flesh of puffers contains a toxin called tetrodotoxin, which is one of the deadliest nerve poisons known. The toxin acts as a respiratory block in all animals including humans. However, the Japanese, who are well-known risk-takers when it comes to food, regard pufferfish as a delicacy – the dish, known as *fugu,* is prepared in Japan by specially licensed chefs.

Boxfishes are relatives of puffer fishes, and are encased in a rigid armour of bony plates. The small blue-spotted, yellow boxfishes shown in Figure 10.8 hang in the water column like slowly revolving dice.

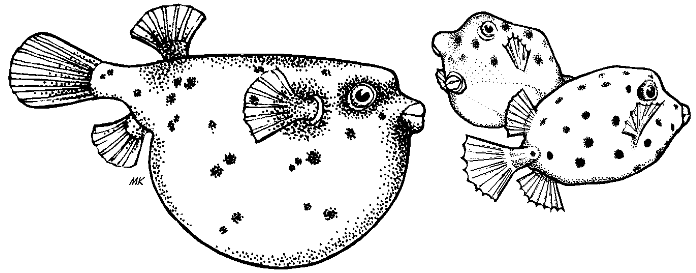


Figure 10.8: At left, the black-spotted puffer fish, *Arothron nigropunctatus;* the fish has a yellow body and grows to a length of 30 cm. At right, the tiny yellow boxfishes, *Ostracion tuberculatus.*

Offshore fishes

The open seas are relatively poor in marine life. Far from land, the sea is a difficult place in which to live – there is no shelter and the food that is available is patchily distributed. But some remarkably fast and efficient predators have evolved to live in such an environment.

Fishes that live in the surface layers of the sea are referred to as pelagic. Large pelagic fishes are nearly all carnivores and the most notable of these voracious hunters are the tunas.

Tunas can swim at speeds of over 50 kilometres per hour to catch smaller fish. And like many fast fishes, tunas have evolved bodies that are fusiform or teardrop-shaped, as it is this shape that offers the least resistance in water.

Some species of tuna, including albacore, move across large areas of the ocean, either to reach new feeding grounds or to reach spawning areas, whereas other species, such as skipjack tuna, may stay in one area for their whole lifespan.

The abundance of tuna is particularly high in areas of upwelling such as in the western Pacific, where the north and south equatorial currents move apart, creating an equatorial upwelling (see Figure 6.3 in Section 6).

Pacific island countries control the use of tuna resources within the area of sea up to 200 nautical miles from their shorelines and reefs in their Exclusive Economic Zones – see “Law of the Sea” in the Box on the following page as well as Table 1.1 and Figure 1.2.

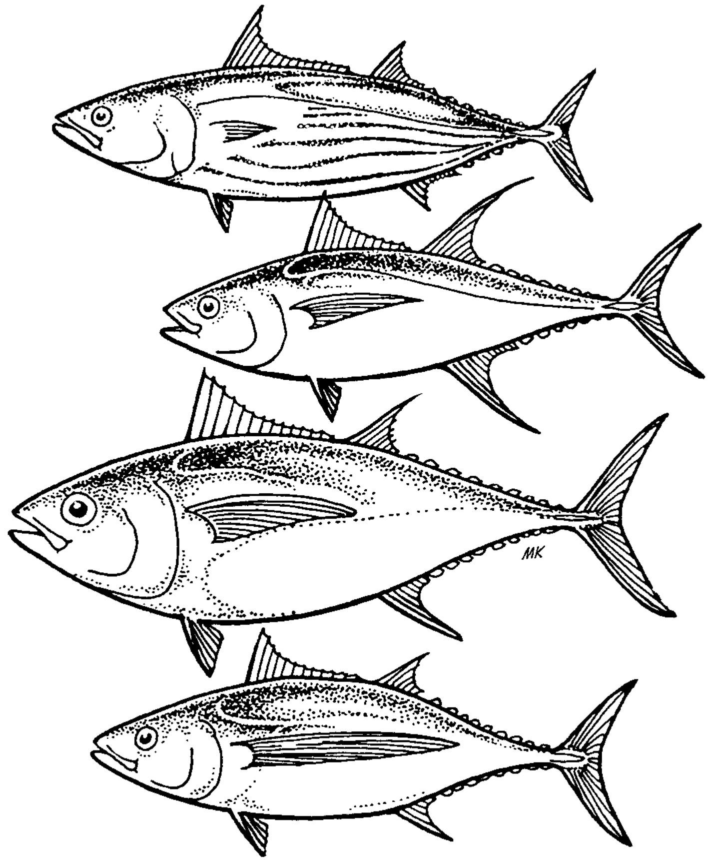


Figure 10.9: Common Pacific tuna. From the top, skipjack, *Kasuwonus pelamis,* yellowfin, *Thunnus albacares,* bigeye, *Thunnus obesus* and albacore, *Thunnus alalunga.*

Law of the sea

Under European law, coastal countries have had jurisdiction over a narrow band adjacent to their coastlines since the 17th century; the width of this band was set at three nautical miles, the range over which a cannon could be successfully used!

In the late 1950s a series of United Nations conferences produced the Law of the Sea Treaty. This treaty allowed countries to take control of offshore areas out to 200 nautical miles from their coastlines, outer reefs or islands. Within this area of open sea, known as the Exclusive Economic Zone (EEZ), a country has the right to control economic activity including exploiting and managing fisheries resources. Many Pacific Island countries gained control over large areas of ocean. In the independent Pacific nations, EEZ areas range from 120,000 km^2 for Samoa to 3,550,000 km^2 for the atoll islands of Kiribati (see Table 1.1.)

Canned tuna is produced in several Pacific islands including Palau, Solomon Islands, Fiji, and American Samoa. Some species of tuna are specially handled for marketing as sashimi. The tuna is served raw with a dipping mixture of wasabi (Japanese horseradish) and soya sauce. Originating in Japan, the popularity of sashimi has spread, and it is now served in sushi bars and restaurants around the world. Sashimi-style tuna is now popular in many Pacific islands.

Other common offshore fishes (Figure 10.10) include the mahi-mahi or dorado. Larger fishes include the Spanish mackerel and the wahoo, both of which can attain weights of over 70 kg. The Indian mackerel is found in coastal waters in Melanesia and the barracuda is found in all Pacific islands. Jacks or trevallies as well as the smaller horse mackerels or scads (family Carangidae) are recognisable because of the scutes, or large rough scales, near their tails. Scads tend to form dense schools and appear seasonally in inshore waters. Sardines and anchovies are common in inshore areas, particularly in estuaries.

Histamine horrors

Histamine poisoning is common in some Pacific islands. The symptoms of histamine (or scombroid) poisoning, which is an allergic response include skin rashes, facial swelling, headache, nausea, vomiting, diarrhea, tingling and palpitations. Certain fish, particularly tuna and mahi-mahi, have high levels of the amino acid histidine that is converted to histamine by the action of certain bacteria. The bacteria multiply rapidly in decomposing fish, and cooking or canning does not destroy the histamine produced. To avoid histamine poisoning, it is important to eat fish that has been properly iced from the moment of capture. Buy fish that looks fresh – eyes that are clear and bright, scales or skin that is shiny, and gills that smell of fresh seaweed, as well having firm flesh that does not separate easily when raw, and is not honeycombed when cooked.

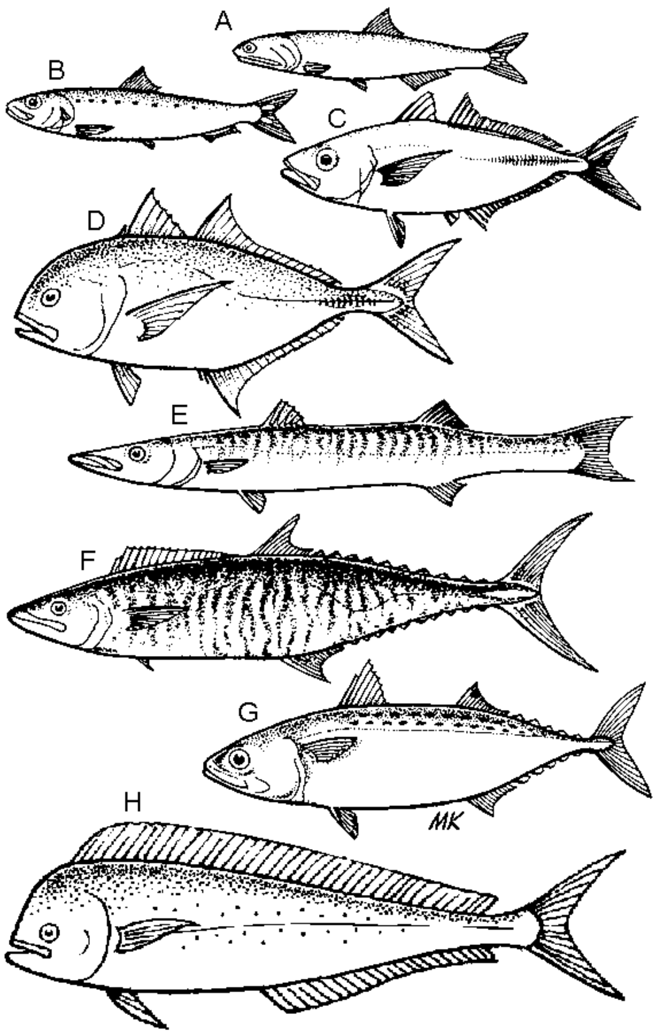


Figure 10.10 (at left):
Pelagic fish of Pacific Islands.

A) anchovies (Engraulidae),
B) sardines (Clupeidae),
C) scads *(Selar, Decapterus),*
D) trevally *(Caranx),*
E) barracuda *(Sphyraena),*
F) Spanish mackerel *(Scomberomorus commerson),*
G) Indian mackerel *(Rastrelliger kanagurta),* and,
H) mahi-mahi *(Coryphaena).*

Countershading

Other than their speed, fish of the open sea have few defenses against predators. In general, and unlike many bottom-dwelling fish, they have no spines, are not toxic, have nowhere to hide, and, seemingly, have no camouflage.

However, most pelagic fish do have a very subtle form of camouflage called countershading. Fish that habitually swim near the surface often have dark backs that shade to lighter underparts.

To a predator swimming below such a fish, the lighter underparts appear the same shade as the sky and the bright surface of the sea. But to a predator such as a sea bird flying above, the dark back of the fish merges in with the deep blue of the sea.

11. Other marine vertebrates – from snakes to whales

About 360 million years ago, some early lobe-finned fishes crawled out of rivers and lakes. These eventually became the amphibians (frogs, toads and salamanders) and these gave rise to the reptiles, including the giant lizard-like animals called dinosaurs. The only reptiles presently in existence are the snakes, lizards, tortoises and crocodiles. And some of these reptiles, possibly in the face of severe competition on land, returned to the sea.

Reptiles – snakes, crocodiles and turtles

Some snakes, the sea kraits, live in the sea but have to come ashore to lay eggs. However, true sea snakes (family Hydrophiidae) bear live young in the sea and have flattened oar-like tails. Although air-breathing, sea snakes can submerge for up to eight hours.

Some sea snakes grow to over two metres in length and have venom that is more toxic than that of poisonous land snakes. However, sea snakes are less deadly because of their small mouths and poor injecting apparatus. Some will approach swimmers but are generally not aggressive. Nevertheless, as the venom from one snake is sufficient to kill three people, the snakes should be not be approached or provoked.

One particular species of crocodile, the saltwater crocodile, is well known for its ability to live in the sea. The saltwater crocodile is usually found in brackish waters and in rivers from India to Papua New Guinea and northern Australia. However, because of their voyaging ability, they may be found out into the Pacific as far as Fiji. The saltwater crocodile is the world’s largest living reptile, but not quite the size depicted by Hollywood. Even so, a large male has massive crushing jaws and can grow to over six metres (23 feet) with a weight of about 1.5 tonnes.

At about the time of the last of the dinosaurs, ancient terrestrial tortoises entered the seas and eventually evolved into the seven or so species of sea turtles that exist today (Figure 11.1).

With their limbs modified into flippers, turtles are excellent swimmers but must return to the surface to gulp air. And, although turtles mate at sea, their eggs, like all reptilian eggs, can only develop on land. Turtles may travel thousands of kilometres across oceans, but females have to leave the water to lay their eggs in pits that they dig on sandy beaches. Human predators, however, often wait and watch for the nesting turtles and along with dogs and pigs steal the eggs for food.

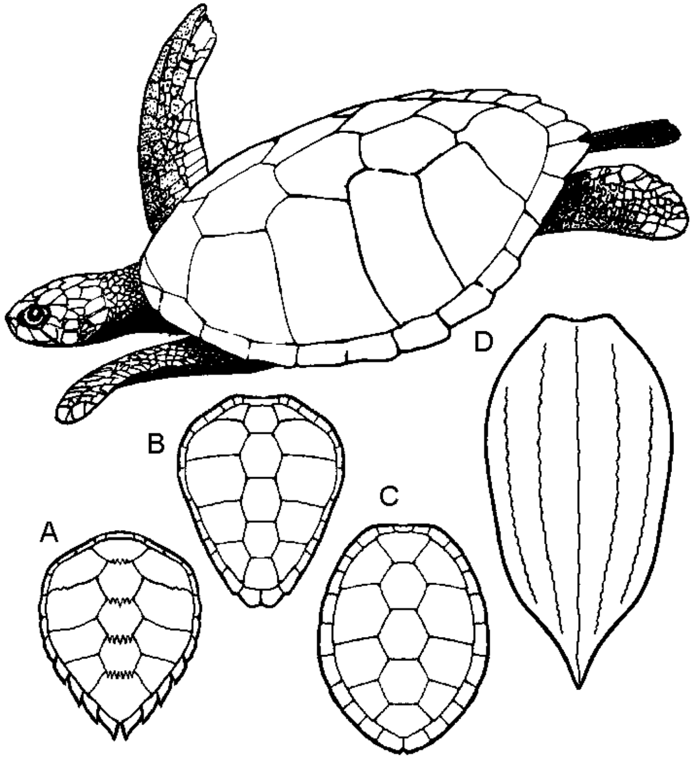


Figure 11.1: A green turtle with the carapaces of
A) hawksbill turtle, *Eretmochelys imbricata,* (90 cm length),
B) loggerhead turtle, *Caretta caretta,* (110 cm),
C) green turtle, *Chelonia mydas,* (110 cm), and,
D) leatherback turtle, *Dermochelys coriacea,* (180 cm).

The widespread hawksbill turtle, which is found in all tropical oceans near rocky and coral reefs, is unfortunate enough to have a carapace or shell that is attractive. The shell can be polished to give the red, brown and black patterned “tortoise-shell” used in ornaments and the species has been hunted for this material.

The green turtle, one of the few larger animals that feeds directly on seagrasses, is found in all tropical waters. This species is the one most commonly hunted in Pacific islands for its meat and green turtle populations have been reduced to dangerously low numbers.

The remaining five species of turtles are either omnivorous or carnivorous. The loggerhead turtle, which is distributed in all subtropical seas, eats crabs and molluscs. The flatback turtle of northern Australia is one of the few animals that eats sea cucumbers as well as other invertebrates.

The largest of all the turtles, and perhaps the most endangered, is the leatherback, which grows to a length of almost two metres and a weight of about 500 kilograms. Instead of the usual horny plated shell this peculiar species has a leathery carapace with distinct ridges. Although the species can be found in cooler waters, it returns to tropical beaches to lay its eggs.

Mammals – dugongs and whales

Sometime during the reign of the reptilian dinosaurs, a new type of animal appeared on earth - warm-blooded, covered with hair and suckling its young. These were the mammals, and by the time the reptiles were at their peak, there was already a number of mouse-sized nocturnal creatures in this group.

But it was only after the demise of the dinosaurs that the number of mammals increased dramatically to fill the vacant habitats and niches. During this expansion, about 60 million years ago, mammals produced a few representatives that ventured into the sea, perhaps in search of new food sources or safety from predators.

Over time, most of these newly arrived marine mammals lost much of their hair but still retained some mammalian habits such as suckling their young with milk.

One group of marine mammals, the sea cows (order Sirenia) is represented at present by only two species - the Indo-Pacific dugong, *Dugong dugon,* (Figure 11.2) and its Caribbean relative the manatee.

Dugongs are sluggish, comical-looking giants, which are believed to be distant relatives of the elephant. They feed almost exclusively on seagrasses and can grow to a weight of 400 kilograms.

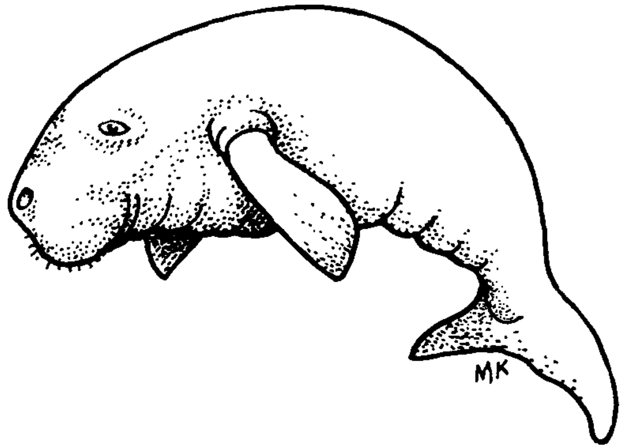


Figure 11.2: Dugong, *Dugong dugon*

Dugongs are protected by law over much of their range, but loss of natural habitat, traditional hunting and incidental drowning in gill nets are reducing their numbers. In the western Pacific, they are found in New Caledonia, Palau, Papua New Guinea, the Solomon Islands and Vanuatu.

Of all the mammals that have returned to the sea, the dolphins and whales were some of the first to successfully colonize the open ocean. Whales do not depend on the land at all and have evolved the ability to mate and give birth at sea. But they are still mammals – they are warm-blooded and bear live young that are nourished with milk.

Whereas large land mammals have had to develop strong skeletons to support their bodies, whales have no such requirement. With their buoyant bodies supported and cushioned by the sea, whales were free to evolve into huge sizes. At up to 35 metres (100 feet) in length and weighing up to 150 tonnes, the blue whale is bigger than any of the dinosaurs ever were. Whales are divided into two groups, the toothed whales and the baleen whales.

There are about 65 species of toothed whales, ranging in size from the smaller porpoises and dolphins, about the size of a human, to the deep-diving sperm whale, which grows to a length of about 20 metres.

Killer whales, or orcas, are easily distinguished by their tall dorsal fins and striking black and white bodies. They are distributed in all waters of the world and males may grow to over nine metres in length. Orcas are highly intelligent and hunt in packs in a highly organised way, taking seals and dolphins.

The sperm whale, or cachalot, is the largest of the toothed whales. With its enormous bulbous head, this is the whale that is most often caricatured in cartoons and described in literature. Many of the old sea stories of monsters attacking ships were fancifully based on this species. The sperm whale roams all ice-free seas, and migrates seasonally from Antarctic to tropical waters.

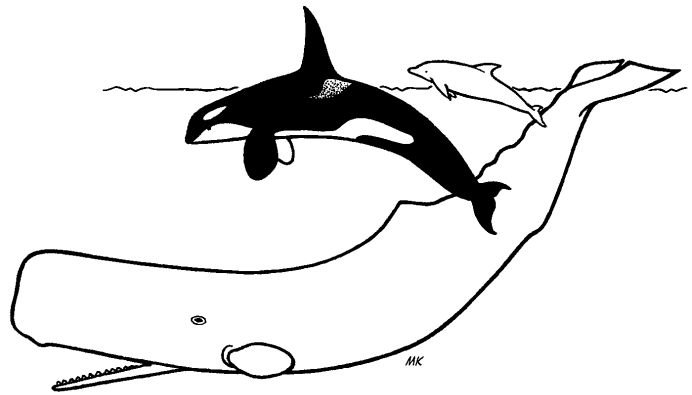


Figure 11.3: Toothed whales.
From top right, examples show the bottlenose dolphin, *Tursiops truncatus,* (2.8 metres in length), the killer whale, *Ocinus orca,* (9 metres), and, the sperm whale, *Physeter catodon* (20 metres)

Of all the air-breathing animals that dive, the sperm whale is the expert (see Box “Diving deep down under” later in this Section). It can dive rapidly to depths of over 2000 metres and remaining submerged for periods of an hour or more.

The sperm whale’s diving ability secures it a deep-sea diet that includes fish and giant squid, swallowed whole and digested in their multichambered stomachs.

Baleen whales (Figure 11.4) are even larger than the toothed whales, but in spite of their size, feed on some of the smallest creatures in the ocean. The whales are so-named because of the set of bristly slats attached to their upper jaws, the baleen, which is used as a giant sieve. The main food item is the small shrimp-like crustacean called krill that must exist in unbelievably massive schools. The blue whale, for example, can sieve and devour as much as 8 tonnes of krill each day.

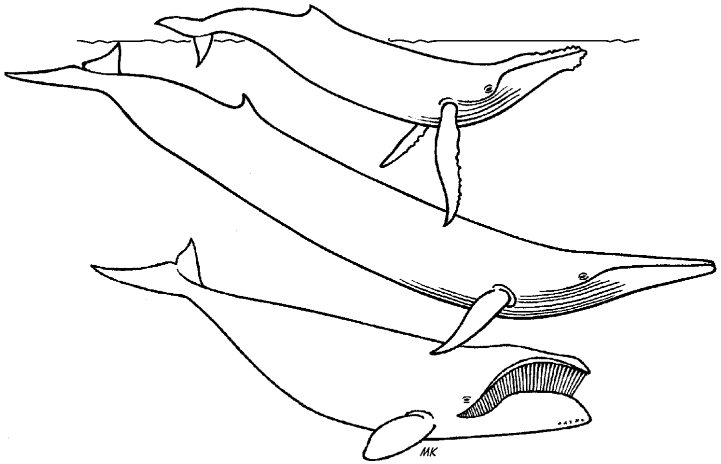


Figure 11.4: Baleen whales.
From the top, examples show the
humpback whale, *Megaptera novaeangliae,* (14 metres),
blue whale, *Baleanoptera musculus,* (28 metres), and
bowhead whale, *Balaena mysticetus,* (16 metres).

There are very few coastal countries of the world where whales are still hunted by local people for food. In earlier times the hunting of whales was an important community undertaking, and provided a welcome and abundant source of protein. Every soft part of the whale was used as food, including the lungs and intestines, and the solid parts were used to make long-lasting artefacts that were both practical and symbolic.

The problem for whales came when they were hunted commercially by Europeans and North Americans. In the eighteenth and nineteenth centuries, whaling became a business, and sailing ships traveled across the Pacific to hunt the sperm whale for its oil-containing blubber and spermaceti. The blubber stripped from a large sperm whale was boiled in cast iron (trying) pots set up on the deck of the whaling ship or ashore at makeshift camps and stations. Over 6 tonnes of oil could be rendered from a large sperm whale and a catch of about 30 whales would fill a whaling ship. The oil was eventually used to make margarine, soap, cosmetics, pharmaceuticals, and glycerin for explosives.

By the 1960s, factory ships were killing and processing 25,000 sperm whales each year, six times the catch of the century before. Under this sort of hunting pressure the stocks of many whale species were greatly reduced and some, such as the bowhead whale, which was protected as early as 1935, were almost driven to extinction.

Staying deep down under

A strange aspect of mammalian physiology is that blood acidity provides the cue to breathe. As oxygen in the blood is depleted and carbon dioxide increases, the latter forms carbonic acid and this lets the blood's owner know that it's time to breathe again. Some underwater spear-fishers deliberately over-breathe, taking many deep breaths in quick succession, to remove residual carbon dioxide before diving and extend the time that they can spend underwater. The practice, if overdone, is quite dangerous as the diver may run out of oxygen before the build up of carbon dioxide indicates it's time to breathe – this could result in the diver passing out underwater from lack of oxygen.

Marine mammals don't take in large quantities of air before diving as this would increase their buoyancy and make swimming down difficult. Most, however, possess mechanisms that allow them to spend amazing times without breathing and to reach spectacular depths. The sperm whale can dive to depths of over 2000 metres and remain submerged for over an hour.

In diving mammals in general, the heart rate slows down, and the flow of blood to the muscles is reduced. The dark blood has a great ability to carry oxygen, and is reserved to keep the heart and brain operating. The brain may be permanently damaged if supply is cut off for more than a few minutes. When the blood in the brain becomes deoxygenated and acidic the mammal will need to come to the surface and breathe.

Since commercial whaling was stopped in 1986, the numbers of whales have increased dramatically. The banning of whaling, even if not universally adhered to, has resulted in some whales being able to rebuild their populations.

In the Pacific, numbers of the humpback whale are rebuilding, and millions of whale-watchers are being thrilled by its arched-back dive and huge wing-like flippers, and mesmerized by its long ethereal "songs". Whale watching in some areas in the Pacific, such as in the Vavau Islands of Tonga, has boosted income from tourism to local communities.

12. The exploitation of marine species

In Pacific islands, seafood has traditionally been the most important source of protein. However, catches of the most accessible seafood, fish, seaweed and shellfish of the lagoons and reefs, have been declining in some islands over many years. Reasons for the decline in inshore catches include increasing population sizes, the use of overly efficient and destructive fishing methods (including the use of explosives, chemicals and traditional plant-derived poisons), and environmental degradation.

Fishing Gear and Methods

In the Pacific, fishing methods vary from the simple hand collection, or gleaning, of reef species to the offshore netting of tuna.

Reef Gleaning

The collection of marine animals and seaweed in lagoons or on the reef flat at low tide is a common activity usually practised by women and children. Gleaned species include sea cucumbers, sea urchins, crabs, molluscs, seaweed, eels, small fish, worms, jellyfishes and octopuses. Collection can be done by hand, by digging in the sand for buried molluscs, by overturning or breaking corals and rocks, and by using sticks and metal hooks to draw octopus, crabs or fishes from holes in the reef. Although the volume of food collected by one person in this manner may be quite small, the combined impact on the reef and marine life can be substantial.

Traps

Baited traps or pots are used to catch various carnivorous species of crustaceans, molluscs and fishes. Traditional traps made of wicker or cane and baited with sea urchins or chitons have been used to catch lobsters in Samoa, Vanuatu and Tonga, but at present, most are caught by spear or hand. At present, such traps are regularly used in Micronesia and parts of French Polynesia.

Barrier and fence traps represent perhaps one of the oldest ways of communal fishing. The simplest traditional traps use the ebbing tide to strand fish in hollowed out areas on reefs and sandbanks, and are contained by v-shaped or semi-circular walls of stone or coral. Fence traps (Figure 12.1) usually consist of a wall built at right-angles from shorelines and reefs to guide migrating coastal fish such as mullet into a large retaining area. Fish may be either isolated in the retaining area by the retreating tide, or prevented from escaping by a complicated design or maze. Fish are collected from the trap by hand or by using spears or nets.

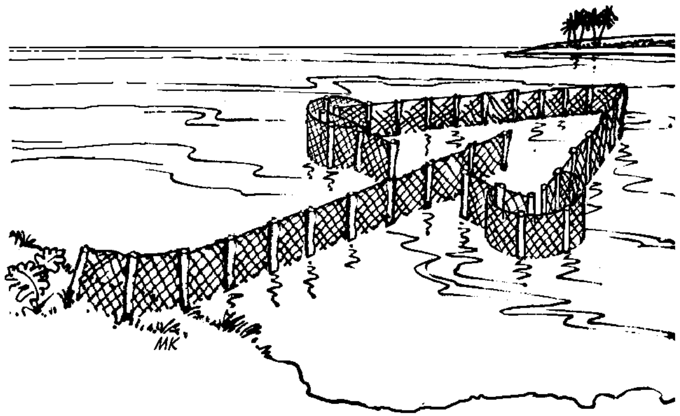


Figure 12.1: A fence trap used to catch migrating coastal fish.

Designs of fence traps are often traditional, and vary between regions. Originally made from stone or coral blocks, fence traps are now usually made from modern materials such as wire-mesh netting (Figure 12.1). Traps may be owned by a single family or by a whole community. Their ease of construction, and their use by increasing populations, have resulted in authorities limiting the number of fence traps in some areas.

Hooks and lines

Hook and line gear is used in a wide range of configurations, the simplest being a hand-held line with one or more baited hooks. The most familiar type of manufactured steel hook is J-shaped, with the pointed part of the hook more or less parallel to the shank (Figure 12.2).

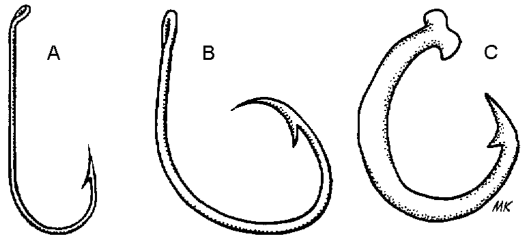


Figure 12.2: Fish hooks, including, from left,
A) a common J-shaped hook,
B) a modern circle hook, and
C) a Pacific Island traditional bone hook

Circle hooks are similar in design to the bone or shell hooks which have been used since prehistoric times in Pacific Islands. When a fish strikes a circle hook, the point rotates around the jawbone, ensuring that the fish remains caught without the fisher having to maintain pressure on the line. Steel circle hooks are used by commercial fishers to catch tuna, sharks and deepwater snappers.

Longlines

A longline consists of a main line with hooks set on short sidelines or snoods. A horizontal longline may be set near the surface for pelagic fishes such as tuna (Figure 12.3), or on the sea floor for demersal species such as sharks. Horizontal longlines set by fishers in the Samoan tuna fishery are from 8 to 40 km in length.

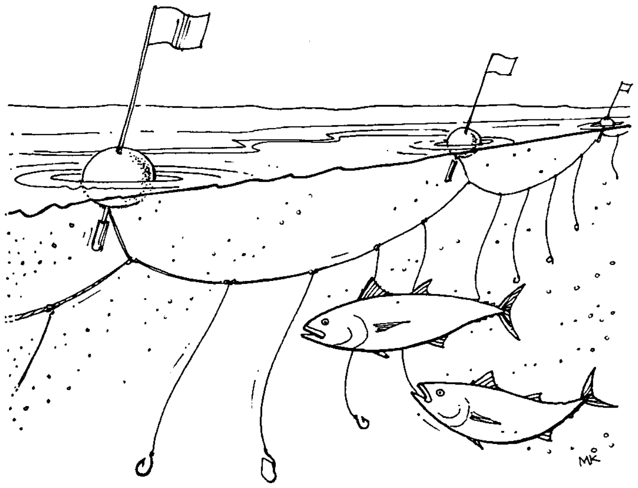


Figure 12.3: A tuna longline.

Trolling and lures

Natural or artificial lures attached to lines may be towed (or trolled) behind boats to catch pelagic species, such as mackerel, dolphinfish and tuna.

In general, lures are designed to attract fish by having one or more of the following characteristics - an erratic movement when towed through the water (to resemble an injured prey), a bright or reflective surface, and fluttering appendages of feather, plastic, rubber or cloth.

Instead of artificial lures, small silver fish such as garfish and flying fish, or pieces of larger fish, may be threaded onto a series of hooks (Figure 12.4).

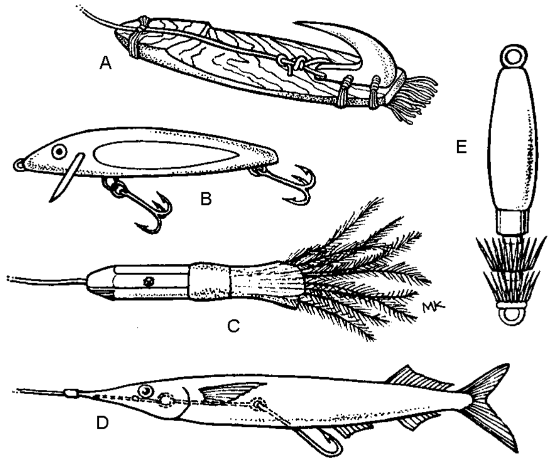


Figure 12.4: Fishing lures including A) a traditional pearl-shell lure from Kiribati, B) a "hard" fish lure, C) a "soft" fish lure, D) a lure baited with a garfish, and, E) a squid jig.

Tuna may be caught commercially by pole-and-lining, involving the use of barbless, unbaited hooks, or pearl-shell lures with a barbless hook, on short lines attached to poles. The tuna are often encouraged to strike the bright metal hooks by "chumming" the water with live baitfish to induce a feeding frenzy.

Traditionally, pole and line fishing was an important communal fishery using live bait and mother-of-pearl lures to catch skipjack tuna. The fishery in French Polynesia is now a highly developed and competitive industry, supplying fresh tuna to the local markets.

Squid are also caught commercially on barbless lures, or jigs (Figure 12.4) attached either to hand-lines, or to automatic jigging machines. The machine automatically lowers the line to a set depth, and an elliptical drum retrieves the line with a jerking or jigging movement. During night fishing, bright lights are used to attract squid into the fishing area.

Gill nets and barrier nets

Gill nets are panels of netting held vertically in the water column by a series of floats attached to their upper edge (the floatline, or corkline), and weights attached to their lower edge (the footrope, or leadline). The nets are often made from almost invisible monofilament nylon strands, which lock behind the gill covers of bony fish or the gill slits of sharks.

In shallow water, gill nets are used to catch species such as mullet and mackerel. In deeper water they may be set on the sea-floor for species such as sharks, or near the surface for fish such as tuna.

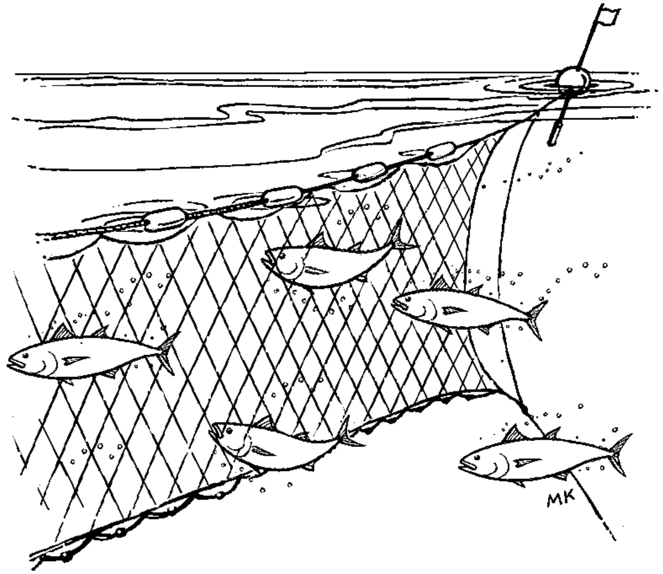


Figure 12.5: A gill net.

Barrier nets can be set across reef passages and channels to trap fish on the falling tide. Often the barrier net is set in a V-shape with the point of the V lying in deeper water. As the tide falls the fish are eventually trapped in the point of the V.

Seine nets and drive-in netting

A beach seine in it simplest configuration consists of a long panel of netting which is dragged around shoreline schools of fish. The net is weighted to keep the lower side of the panel in contact with the sea-floor, and has floats to keep its upper side at the surface.

Drive-in net fishing is a group activity that often involves the whole community. Nets are set in a shallow part of the water and fish are driven into the net by swimmers and scare lines. Fish may be herded with coconut leaves tied to a rope or scared by splashing the water surface with sticks.

Out in the open sea, large ships use purse seine nets (Figure 12.6) to encircle schools of skipjack and juvenile yellowfin tuna. These sophisticated purse-seine vessels are fitted with sonar and sometimes a ship-based helicopter to locate schools of fish. A purse seine net is a long panel of netting, up to 2 kilometres in length, with floats fastened to its upper edge and weights and purse rings attached to its lower edge.

Once a school is located, the end of the net is attached to a buoy or a skiff, which is cast off. The vessel releases more and more of the net as it moves around in a large circle, which is completed when the two ends of the net are brought together. After the net ends are retrieved, the purse wire, which runs through the rings around the lower weighted edge of the net, is hauled in to close off the bottom of the net, and prevent fish from escaping downwards. There are concerns about the devastating efficiency of purse seines, which can catch over 100 tonnes of fish in a single shot of the net.

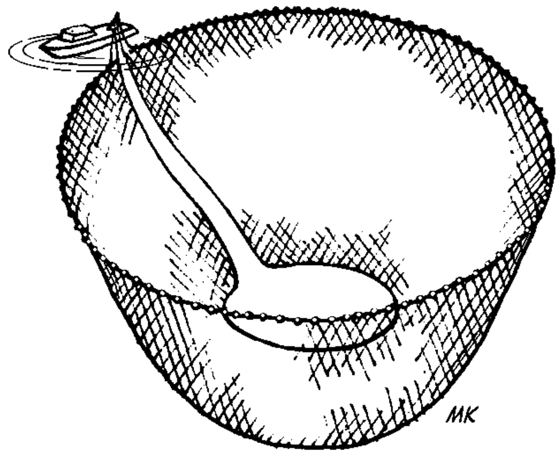


Figure 12.6: A purse seine net set from a tuna fishing vessel (top left-hand corner).

Cast net and scoop nets

Cast nets are used in shallow water to catch schooling species such as mullet, rabbitfishes and scad. Fish are stalked in shallow water and a circular, weighted net is thrown so it spreads horizontally over the school like a parachute, entangling the fish in the net.

Flying fish are caught at night from canoes in Polynesia by fishers using hand-held scoop nets and lanterns. The light is used to daze the flying fish, which are then scooped up by the net.

Spears

Spears may be used from land or a boat, or by diving beneath the water with sling-type spears and spear guns. People often use torches and spears at night to catch fish at low tide.

The use of modern, underwater flashlights has had a large impact on inshore marine life. Larger fish from the reef edge come in at night to sleep among the corals for protection from predators. This makes them an easy target for a fisher with a flashlight and spear. Masks, fins, SCUBA gear, steel spears and spear guns have also increased the effectiveness of spearfishing.

Fish aggregation devices (FADs)

Many fishes that inhabit the open sea are attracted to floating objects; some tunas, for example, congregate around drifting logs. This behaviour has been used in the deployment of fish aggregation devices (FADs) - floating rafts anchored offshore to attract pelagic fish. A typical FAD is moored to a concrete block set in depths of over 1000 m. (Figure 12.7).

Material such as old fish nets, palm leaves, and car tyres are suspended beneath the rafts in the belief that this increases the raft's effectiveness as a habitat for fish. FADs are used to attract pelagic fish, including tuna, for fishers towing lures. A recent development is that fishers are leaving free-floating FADs in the sea to attract skipjack tuna.

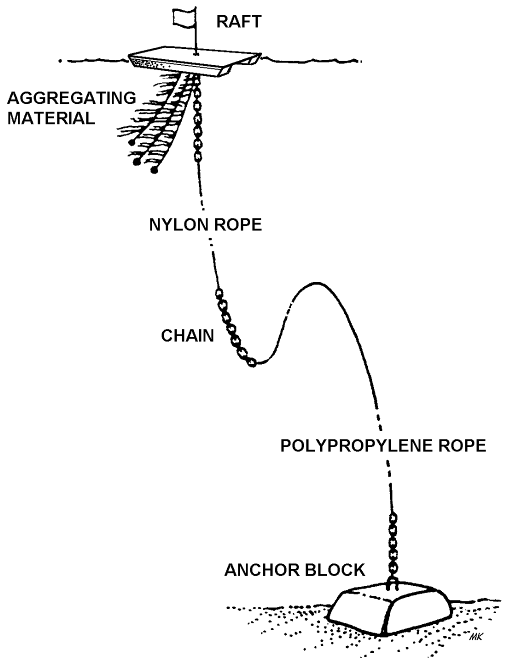


Figure 12.7: A fish aggregation device, or FAD, used to attract pelagic fish.

Threats to seafood species

Other than increases in population sizes (particularly in urban areas) and environmental disturbances, the most obvious reasons for the decline of inshore fish stocks are the use of overly efficient and destructive fishing methods.

The use of outboard motors, for example, has allowed people in communities to fish well beyond their traditional fishing areas. The use of modern materials such as fine monofilament nylon for gill nets, has made fishing effort more effective. Gill nets made of this material are almost invisible in the water and the thin nylon locks more efficiently behind the gill covers of fish.

The fence trap shown in Figure 12.1 was traditionally made of coral blocks and took an entire community many months to build. Such traps are now usually made from wire-mesh netting and can be constructed by a family in a single day. In villages where there was once a single communal fence trap, there are now many traps owned by individual families.

In some cases, quite modest developments such as the availability of underwater torches, which allow the spearing of large fish resting under corals at night, have resulted in a dramatic increase in fishing efficiency.

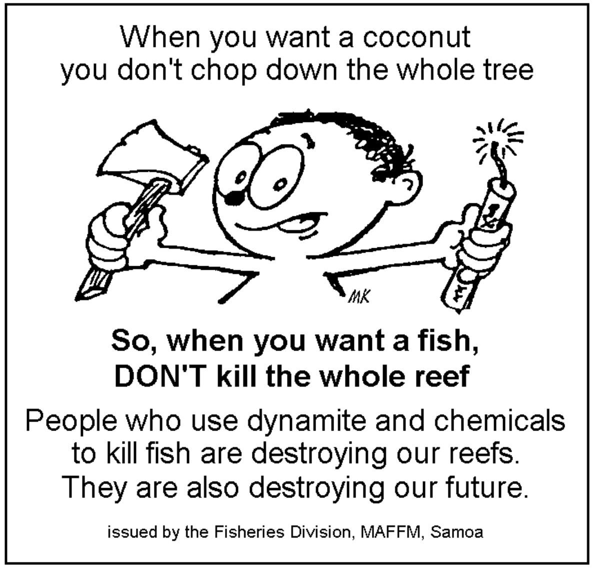


Figure 12.8: An advertisement used in Samoa to raise community awareness of the damage caused by using explosives and chemicals to catch fish.

The use of explosives and poisons to disable and capture fish represents a serious threat to marine ecosystems and the long-term viability of fisheries in several Pacific islands. Bleach (calcium hypochlorite) is poured into pools isolated on the reef at low tide to capture small fish. Explosives are either thrown from a canoe into a school of fish, or set on coral where fish have been encouraged to gather by setting bait.

Explosives and severe poisons are many times more damaging to small animals, such as fish larvae and coral polyps, than they are to larger fish. Coral reefs that have been destroyed by the use of explosives are no longer able to support populations of fish, and the reef may not recover for many years. Dynamited reefs in the Philippines, for example, have taken over thirty years to recover after dynamiting has been stopped.

Some traditional fish drives and collecting activities may involve damage to corals, either directly as a result of breaking coral to catch sheltering fish, or indirectly through the impact of many people moving over the reef. In the past the marine environment was more able to sustain such damage because the frequency of the activity was low and fewer people were involved.

In many Pacific countries toxic plant material is used for fishing. The poisons are derived from the roots of the climbing vine, *Derris elliptica,* and the nut of the coastal tree, *Barringtonia asiatica,* which are ground into a paste and wrapped in small parcels made of leaves; fishers drive fish into the shelter of a preselected coral head where two or three parcels of poisonous material have been placed.

With the number of people increasing rapidly in many Pacific islands, at least in urban areas, there are many cases in which there are too many people fishing for too few fish.

A population or stock of fish, and the forces acting on it and controlling its numbers, are shown in Figure 12.9. The number of fish is being increased by the reproduction of adult fish, which eventually results in small fish being added, or recruited, into the stock. The fish stock is being reduced in numbers and biomass by predation (being eaten by another animal) and, in exploited species, by being caught by fishers.

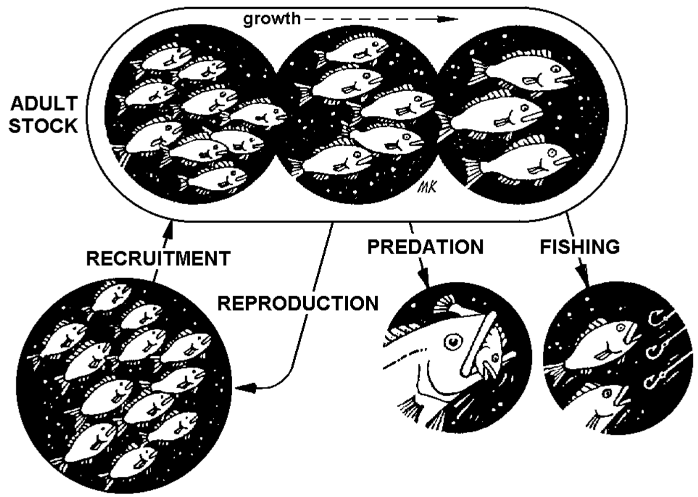


Figure 12.9: An exploited fish stock (top elongate shape) is increased in weight by reproduction, which results in the recruitment of young fish (lower left circle) back into the stock. At the same time, the stock is being reduced by predation and, in exploited species, by fishing.

If a fish stock is not exploited or is fished at a low level, losses are balanced, on the average, by gains through reproduction and the addition of young fish. Numbers in the stock will therefore fluctuate around an average level. It is for this reason that fish are referred to as a renewable resource. That is, fish can continue to be used as food forever, as long as the numbers caught are replaced by young fish. If exploitation is high, however, the number of adult fish may be reduced to a level where reproduction is unable to replace the numbers lost. In this case, fish stocks will decrease.

Stocks of seafood will also decrease if the marine environment on which they depend is degraded. The coastal environment that supports marine species is in demand and being affected by recreation, industry and development. The dilemma is, that as the need for seafood resources is increasing, the ability of the marine environment to sustain these resources may be decreasing.

Many fish stocks have been fished down to very low numbers and some particularly vulnerable species have been driven to extinction in localised areas. Some species of giant clams are now extinct in Micronesia and one species has disappeared from Vanuatu and Fiji since the 1970s. Stocks of mullet, which have been caught in large numbers in fence traps, are now very low in some islands. In various islands, stocks of pearl oysters, green snails, coconut crabs and sea cucumbers have all been reduced.

The renewability of fisheries resources depends on our ability to ensure that too many fish are not caught. This implies that fisheries, and particularly the amount or types of fishing, have to be controlled or managed.

Fisheries management and regulations

In order to manage fisheries, it is usually necessary to apply one or more regulations. These either control the amount of fishing, restrict the amount caught, or protect the marine environment.

National fisheries regulations are usually enforced by government fisheries staff or police officers. An alternative, discussed later, is where fishing communities devise and enforce their own fisheries regulations. The following sections describe some types of fisheries regulations used in Pacific countries.

Limiting the number of fishers

Limiting the numbers of fishers is usually done by issuing a set number of fishing licenses. In the Cook Islands, for example, a set number of licenses is issued for people to collect trochus. In Samoa, a number of licenses is issued for fishers to participate in the tuna longline fishery. Some village communities in Samoa have limited the number of fishers permitted to construct and use fence traps.

In the past, numbers of fishers were controlled, in effect, by restrictions in access to a community fishing area. Trespassers who fished without permission in an area would be punished by clan leaders. Some communities with strong traditional control over marine resources are still able to practise this. However, in many islands, public ownership of the sea now extends up to the high tide mark. The increasing mobility and range of fishers has also made it difficult for communities to control people fishing in their traditional fishing grounds.

Limiting the efficiency of fishing gear

The use of some highly efficient fishing methods may be restricted in the interests of conserving fish stocks and allowing more people to use the resource. Limitations on gear types may include banning a specific fishing method in particular areas, or on a particular species. For example, the use of gill nets in lagoons may be banned, or the use of SCUBA diving to catch lobsters may be prohibited.

Commercial gillnetting has been banned by communities in parts of Fiji and this is supported by the government – in order to obtain the necessary government-issued license for commercial fishing the applicant must first obtain permission from the customary fishing rights holder. In Tuvalu, net fishing in the lagoons is also banned or strictly controlled by chiefs in some of the outer islands.

In Samoa some communities have placed restrictions on the use of underwater torches for spearfishing at night. In some subsistence fisheries, the survival of the resource depends on inefficient exploitation!

Banning destructive fishing

Highly destructive methods of fishing, such as those involving the use of chemicals, bleaches or explosives are usually illegal, even though widely practised, in many Pacific islands. Some village communities, including local clans of Marovo lagoon in the Solomon Islands, have enforced these prohibitions. Communities elsewhere have also banned the use of traditional plant-based fish poisons. In Samoa, some communities have banned the traditional smashing of coral to catch small sheltering fish.

Closed areas and seasons

Closed areas can be used to protect juveniles and the spawning stock. Mangrove areas, for instance, are known to be nursery areas for many species and are permanently closed to fishing in some coastal areas. In some countries known breeding areas for species such as trochus are permanently closed to fishing.

If the spawning season of a particular species is known a closed season at the time of spawning may allow adults to breed without interference.

Turtles, for example, are protected in some countries during the egg-laying months of November to February. Villages in Vanuatu have periodically banned the collection of trochus and green snails for specific periods. The closures were similar to customary taboos in design and enforcement but were also based on biological information provided by government fisheries staff.

The exploitation of sea cucumbers for the export market in the atoll of Ontong Java in the Solomon islands was high until village leaders closed the fishery during alternate years. In the years closed to sea cucumber fishing, the lagoon is open to trochus diving.

In Samoa, many village communities have chosen to establish small areas closed to fishing in part of their traditional fishing areas. Although these community-owned marine protected areas are small, their large number, often with small separating distances, forms a network of shelters for fish around the coast. Such a network may provide the means under which adjacent fishing areas are eventually replenished with marine species through reproduction and migration.

Minimum mesh sizes

Minimum mesh sizes in nets, and escape gaps in traps are applied in many fisheries to allow small individuals to escape and grow to a size at which they can reproduce at least once before capture.

In many island countries, governments have imposed mesh size regulations, and rules set by local fishing communities can support and enforce these regulations. Some communities may set their own larger mesh sizes, to further reduce the catch of small fish.

Size limits (minimum legal lengths)

Limiting the size of individuals caught involves returning captured individuals smaller than a prescribed minimum size to the sea. Traditionally, size limits have been applied to allow individual fish to spawn at least once before capture.

Minimum legal sizes have been applied by national governments in Pacific islands to many species including sea cucumbers, trochus, pearl oysters, giant clams, spiny lobsters, mangrove crabs and many species of fish.

Size limits are only useful in fisheries where individuals are not harmed by the catching method, such as molluscs gathered by hand, or crustaceans caught in traps. Although some shallow-water fish caught on hooks may survive well if returned to the water immediately, this type of regulation has little application to spear-caught and deepwater fish species. Fish caught in deep water are unlikely to survive after being hauled to the surface and released.

Some village communities in Samoa have set their own minimum size limits, which are larger than those set under national regulations.

Rejection of females, or spawning females

Regulations making it illegal to retain females, or females bearing eggs, can only be applied sensibly to species in which the sexes can be distinguished easily and where the catching method does not harm the individuals caught.

Many countries have regulations making it illegal to retain egg-bearing, or "berried", lobsters and crabs. The regulation is useful in cases where lobsters and crabs are caught in traps, and females bearing eggs can be returned to the sea. However, in cases where these crustaceans are caught by spearing, the regulation is of little use.

Catch Quotas

Fisheries agencies may determine that, in order to protect fish stocks, total catches should not exceed a certain amount called a quota. In the trochus fishery in the Cook Islands, for example, it has been estimated that fishers should be allowed to catch about 30% (equivalent to about 40 tonnes) of the total trochus stock each year. Once this quota has been reached the fishery is closed.

Community-based fisheries management

In Pacific islands, as elsewhere, government agencies or departments are responsible for managing and conserving fish stocks and protecting the marine environment. Most countries have national fisheries regulations and, although these may be applied in urban areas, they are rarely enforced in village areas.

Subsistence fisheries, those that provide food for local people, are difficult to manage. They are made up of a large number of fishers using many different fishing methods to make small individual catches of a great variety of species from around the entire country.

One way to ensure that subsistence or village fisheries are sustainable is for fisheries agencies to encourage and support fishing communities to manage their own fisheries resources. The community sets its own conservation rules, and it (rather than the government) has a responsibility to enforce them. Because communities play a key role, this type of management is referred to as community-based fisheries management.

If communities make their own conservation laws, as they have historically done in the past, they are more likely to respect them.

13. Other threats to the marine environment

In a directory produced by SPREP in 1999 (Coastal Management Profile), local authorities and organisations in individual Pacific islands identified what they regarded as the most important threats to their local marine environment. Many of these issues were also reviewed and discussed in the six volumes of reports prepared by the Strategic Action Programme Project based at SPREP.

The threats of most concern to Pacific island countries can be summarised under the following headings.

- Natural events – including cyclones, seismic activity, tsunami and rising sea-levels.

  and the following threats caused by human activity;

- Degradation of the marine environment – including destruction of habitats and depletion of seafood species.
- Increasing population sizes – including increases in tourism, which also places additional pressure on the environment.
- Reclamation and development – including the building of roads, causeways, homes, factories and hotels.
- Erosion and siltation – including erosion and siltation from mining and forestry.
- Sewage and eutrophication – including the contamination of waters adjacent to towns and villages.
- Wastes, hazardous chemicals and oil - including the use of agricultural chemicals and disposal of solid waste.

Of the issues listed above, threats to various marine habitats and to marine species have been discussed in previous sections. The remaining threats are discussed in this section.

Natural events – cyclones to El Nino

Cyclones and earthquakes, as well as the large waves that they create, present serious and mostly unpredictable threats to Pacific island countries and their coastal environments.

Tropical revolving storms arise from depressions or low pressure areas that have intensified. And when winds exceed 34 knots (63 kph) they are officially classified as cyclones.

Cyclones, called typhoons in some areas, occur in most islands in the tropical Pacific region. The highest number of cyclones appears to strike Melanesia; Fiji and Vanuatu have recorded 34 and 32 cyclones respectively over a 30 year period. Cyclones appear to miss some fortunate countries such as Kiribati.

Winds blow towards the centre of these intense lows. In the northern hemisphere winds are deflected to the right and thus circulate around the low in an clockwise direction. In the southern hemisphere, the situation is reversed and winds circulate around a low in an anticlockwise direction.

North of the equator tropical revolving storms are most frequent from July to September. South of the equator they are most frequent from December to March.

Earthquakes are common in some parts of the Pacific area, particularly in places where there are breaks or discontinuities in the earth's surface.

The earth's surface is not a continuous layer, but is made up of a number of plates, somewhat like a cracked eggshell whose pieces float on and cover the fluid beneath. The separate continental plates that make up the earth's surface are moving very slowly, either towards or away from each other. The boundaries between the plates in the Pacific are shown in Figure 13.2.

Where the plates are moving apart, molten rock, or magma, from over 700 kilometres under the earth's surface, rises through the gap between the plates, and may form new islands (Figure 13.1).

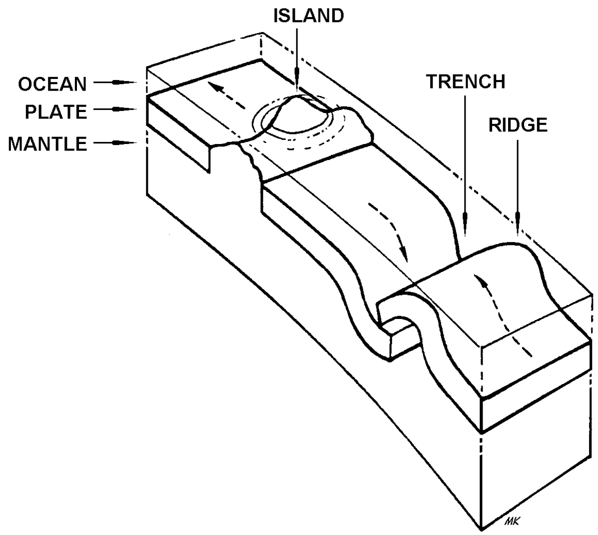


Figure 13.1: The movement of continental plates (shown by dashed arrows).
Where the plates are moving apart, the liquid mantle flows upwards and solidifies to form ridges and islands.
Where the plates move towards each other, they may either fold upward to form a ridge, or one plate may be forced below the other to form a deep oceanic trench.

Where the plates move towards each other, they may fold upwards to form a mountain range or ridge. And one plate may be forced below the other to form a deep oceanic trench (Figure 13.1). The deepest parts of the ocean occur in the trenches formed where continental plates are colliding. And the western Pacific Ocean contains the largest number of these trenches. In the vicinity of Tonga, one plate is being forced beneath another forming the Tonga trench, which is over 10 kilometres deep. In the northern hemisphere, the Marianas Trench, at about 11 kilometres beneath the surface, is the deepest place in all of the oceans.

In Figure 13.2, the continental plate on which Australia sits is moving towards the one on which Hawaii sits at a rate of several centimetres each year.

The boundaries between the continental plates are unstable areas where earthquakes may occur as plates move against each other. Violent earthquakes and tremors occur when a build up of pressure results in a sudden movement of one plate against another. Papua New Guinea area and Tonga, for example, straddle one of these boundaries and are subject to many tremors and earthquakes.

Sometimes the sudden movement of one continental plate against another can result in shock waves, or surges, which travel away from its source or epicentre. These waves are known as tsunami (and sometimes incorrectly called tidal waves).

Although containing many millions of tonnes of water, tsunami travel as a series of low swells across the surface of the sea. At this stage, because the waves are flat bulges less than a metre high and over 150 kilometres apart, they are not usually observed by ships at sea. However, when these low but voluminous waves reach shallow water, friction causes their lower parts to slow down and their upper parts to rise up to form gigantic waves, sometimes over 30 metres high.

A tsunami that hit the northern coast of Papua New Guinea in 1998 washed away several villages and killed over 2000 people. Miraculously, a young village boy survived by diving down to the bottom of the lagoon where he hung on to a coral head while the huge wave passed overhead. Tsunami are particularly dangerous because they strike coastlines without warning. Often, the only indication of one’s approach is a rapid withdrawal of water away from the shore before the first large wave hits.

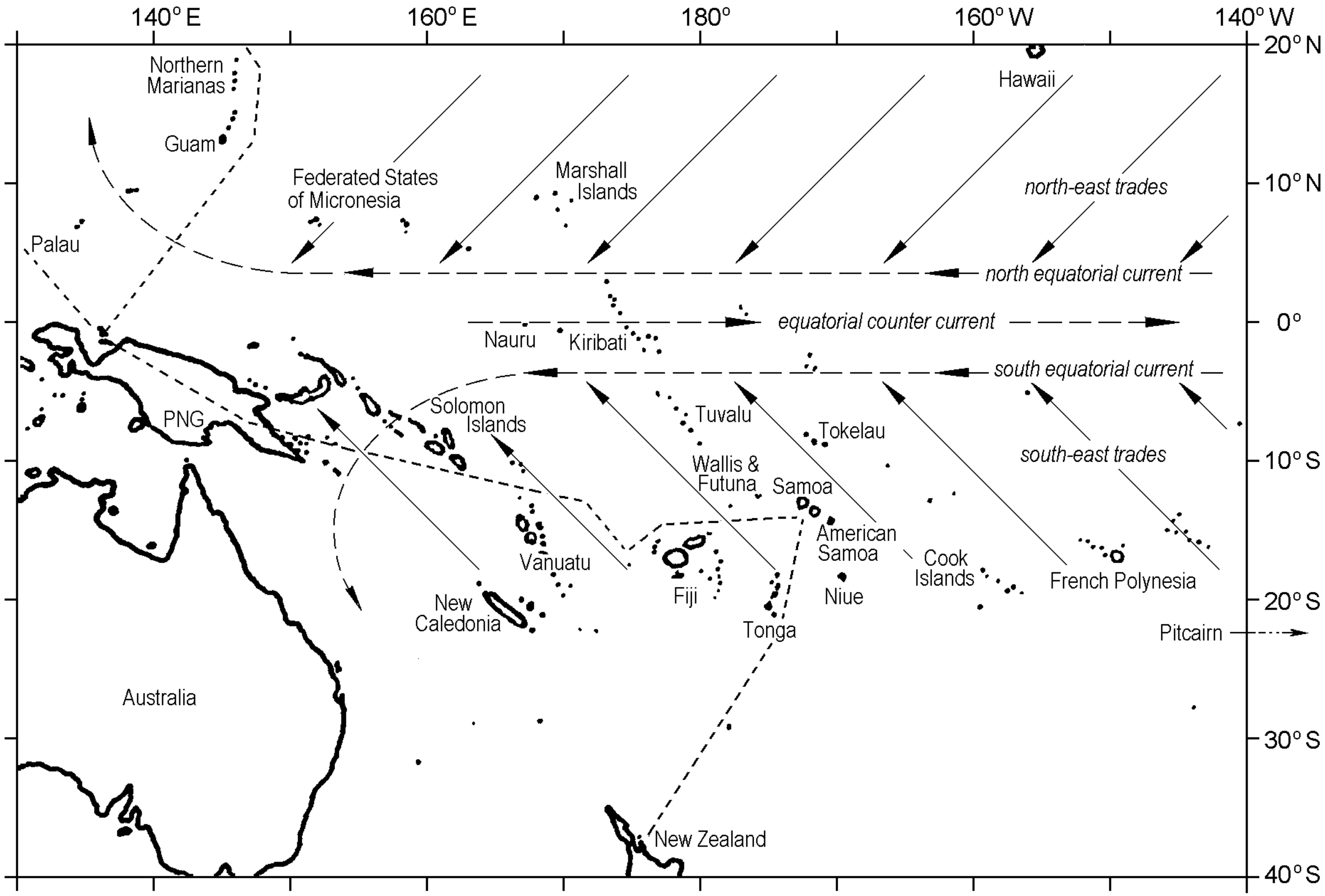


Figure 13.2: The Pacific island region. The northeast and southeast trade winds are shown by oblique lines with arrow heads. Broad dashed lines and arrows show sea currents. Margins of the continental plates are shown as a fine dashed line passing through New Zealand, Tonga (the Tonga trench) and the Marianas (the Marianas trench).

Cyclones and tsunami erode coastlines, destroy corals, and cause devastation to marine life. The most serious of their effects is the reduced ability of the devastated environment to provide food for local communities. Crops can be ruined, drinking water may become contaminated and corals may not recover sufficiently to support seafood species for many years.

Paradoxically, the periodic destruction of coral reefs may actually increase the diversity of coral species. This would be the case, for example, if a reef was dominated by table coral (see Figure 4.1) that prevented light reaching other coral species – high seas breaking up this coral may give other species of coral an opportunity to settle and grow.

Another natural event that periodically affects Pacific islands is El Nino. Although it has its birthplace in the Pacific, El Nino is believed to have a global effect on weather, sea temperatures and sea levels. In Pacific Islands, the major effects are on sea temperatures and water levels.

The normal southeast trades that blow over the southern tropics are created by high-pressure areas in the south (at about 30 degrees south) and low-pressure areas over the equator. The tradewinds are the driving force behind the south equatorial current (Figure 13.2). This current pushes water to the west until the sea level off the north of Australia is about 60 cm higher than it is off Peru in South America.

However, in late November or December each year these pressure systems weaken. As a result, the tradewinds decrease in strength and become more variable in direction. This time, from November to March is the wet season, and the time of cyclones, in the tropical southern hemisphere.

As the tradewinds drop in strength, the south equatorial current also weakens allowing seawater, which has “piled up” on the western side of the Pacific to flow back to the east. The south equatorial current reverses in direction and becomes a tongue of warm tropical water travelling across the Pacific and down the coast of South America.

In Chile and Peru, fishers are well aware of this, as local waters become much warmer than usual. As the phenomenon occurs around Christmas time, it has been called El Nino, the “boy child” in reference to the infant Christ.

The heat trapped off Peru in the pool of warm water, which fuels evaporation, cloud formation and storms, then proceeds to affect weather in different parts of the globe. Wind directions are altered globally, bringing freezing conditions and floods to Central Europe and droughts to South Africa. Other devastating effects have included rainstorms in Chile and Peru (usually dry places), droughts in Indonesia, bush fires in Australia, floods in East Africa, and a rise in bubonic plague cases in New Mexico.

In the Pacific islands region, sea levels in the western Pacific Ocean drop dramatically and water temperatures become abnormally high. In many western Pacific Islands corals, exposed at the extremely low tides during El Nino events, have been killed. In the 1997/98 El Nino event, for example, as much as 70% of corals were reported to be destroyed in some areas of Samoa.

The green-house effect represents another climatic threat, particularly to low-lying coastal areas and islands. The steady rise in sea temperatures as a result of the green-house effect may cause sea levels to rise and thus threaten islands in the South Pacific region. The greenhouse effect involves the trapping of the sun's warmth in the lower atmosphere by high levels of carbon dioxide, methane and other gases.

Greenhouse gases allow the passage of incoming solar radiation but restrict the outgoing infrared radiation reflected from the earth (Figure 13.3). As a consequence of this, the temperatures of the earth's atmosphere and seas are predicted to continue to rise.

Levels of carbon dioxide in the atmosphere, from burning forests, grasslands and particularly fossil fuels such as coal and oil, have been increasing steadily. At present about 24 million tonnes of carbon dioxide are being released into the atmosphere each year and the USA accounts for about 25 percent of this.

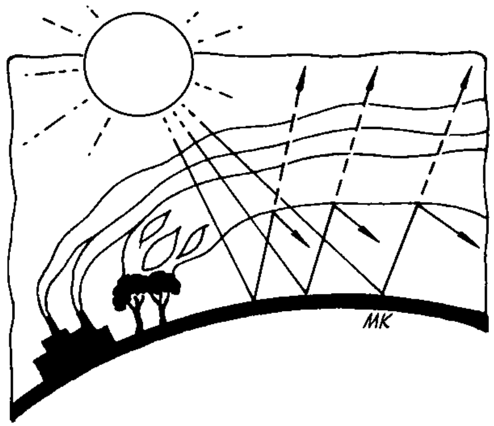


Figure 13.3: The greenhouse effect.
Radiation from the sun enters the earth's lower atmosphere but is prevented from being reflected from the earth by high levels of carbon dioxide, methane and other gases in the atmosphere.

Early in 2001, data from satellites confirmed that greenhouse gases are increasing and that they are producing long-term changes in the Earth's atmosphere. The temperature of tropical seas has increased by one degree over the last 100 years. And some of the more extreme predictions are that global temperatures could rise as much as 5 degrees over the next century.

If the world's temperature is raised, the volume of seawater would expand and melting ice from the poles would add to it. An average increase in world temperatures by 1.5°C to 4.5°C over the next 50 years, could cause a rise in sea levels by 20 to 140 cm. As a result, many low-lying coastal areas would be inundated and the shapes of some continents would change markedly. In the Pacific Ocean, many low coral islands and atolls would be covered by the seas.

Across the Pacific and around the world corals are bleaching and dying (see Section 4). And as coral polyps are sensitive to elevated temperatures, this devastation may be related to the greenhouse effect.

Although the greenhouse-effect can be blamed on the disproportionate use of fossil fuels by developed countries, it is a global problem and the best that can be done is to press for the wise use of fossil fuels by all countries of the world.

The following threats are more directly related to local human activities in Pacific islands.

Increasing population sizes

Many environmental problems, including the depletion of marine resources and the degradation of the environment, can be related to rapidly increasing human populations.

The world's population has now passed the 6 billion mark and is continuing to grow. Each additional person represents another potential source of pollution and adds to the consumption of both living and non-living natural resources.

Populations in many Pacific island countries are increasing at a faster rate than the rest of the world; some islands have rates of over 3% per year. Using American Samoa as an example, the country's population increase rate of 3.7% per year will result in the population doubling in just 19 years.

The large and increasing number of tourists visiting islands with suitable air links also puts pressure on resources and environments. In Palau, for example, tourism is increasing at 20% per year.

Although tourism brings substantial economic benefits, it is essential that governments and industry invest some of the profits into upgrading facilities including those for sewage disposal and water supply.

Many local communities, sometimes with government assistance, are recovering costs associated with the preservation of environmentally valuable areas by charging fees to visitors and tourists. In Palau, fees are charges for tourists visiting conservation areas. Many islands are highly regarded as holiday destinations and the potential for such ecotourism is often high.

There is an urgent need to contain population growth. Not to do so will result in people living in overcrowded islands in which the environment, under increasing stress, is less able to support the growing demand for seafood.

Reclamation and development

In an attempt to gain more waterfront land, coastal areas are often "reclaimed" or landfilled by cutting down mangroves and filling in wetlands with rocks and soil. On Tutuila in American Samoa, for example, over 25% of coastal wetlands and mangrove areas have been converted to dry land for buildings.

The construction of wharves, breakwaters and causeways as well as landfill areas are likely to interfere with water currents, the formation of beaches and the natural movements of fish. The construction of causeways between islets in Kiribati, for example, has blocked the spawning migration of some fish species.

All development in coastal regions will affect the environment to some degree. The building of houses, factories and resorts in coastal areas often involves the clearing of vegetation and landfilling. Construction work may involve blasting channels in reefs and removing sand from beaches. The negative effects of these actions often include reducing the coastline's ability to withstand storms and reducing the environment's capacity to support marine species. The effects of the destruction of mangrove areas, shorelines and coral reefs for the building industry have been discussed in earlier sections.

Erosion and siltation

Erosion refers to the wearing away of the earth's surface by the action of water or wind.

High islands with steep mountains and high rainfall are particularly susceptible to erosion. Rain washing down the mountains erodes soil and causes landslips, sometimes with disastrous consequences. Entire villages have been washed away in serious landslips.

Erosion results in silt being washed into nearby rivers and hence into coastal areas and lagoons. In coastal waters, silt reduces the amount of sunlight penetrating the water, and therefore kills plants and some animals (such as corals) which require light for survival. Silt may also damage the delicate gills of fish.

Mining for metals such as copper, gold and nickel in some high Pacific Islands has resulted in large loads of sediment being released into rivers. In Papua New Guinea, mining waste released into the Fly River system has devastated 200 km of the river and formed shallow banks in coastal deltas. And some fisheries, such as the one for barramundi, have collapsed.

Sand, required for the making of cement in the building industry, has been mined from beaches in an uncontrolled way in many islands. Sand mining activities in Samoa, for example, have exposed shorelines to serious erosion, and the resulting siltation has reduced the depth of water in adjacent lagoons.

Forest trees cut down for local use and for export have been disappearing at such a rate that the resource cannot be renewed without replanting. Without the root systems of trees to hold the earth together, an area is subject to landslips and erosion. In several high islands, including the Solomon Islands, poor land management and logging activities have been recognised as the cause of severe erosion and sedimentation. Erosion can be reduced dramatically by maintaining thick belts of trees on steep hillsides, river banks and coastal fringes.

Clearing land on slopes for agriculture also creates erosion problems similar to those created by mining and forestry operations.

In many localised areas, the clearing of land for kava growing, for example, has caused erosion and water runoff into rivers and coastal areas. In the case of agriculture, erosion can be avoided by sensible management practices, including planting on terraces along contours, and by leaving belts of trees across the slope of the land (Figure 13.4).

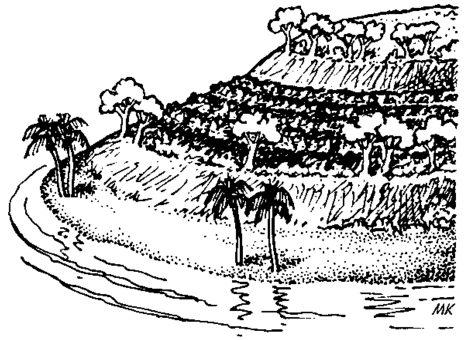


Figure 13.4: Reducing the risk of erosion.
A plantation with terraces built around the mountain side.
Trees are left on the edges of the banks
to prevent erosion and land slip.

Sewage and eutrophication

The most common type of pollution in areas of high populations is caused by sewage - human faeces and urine - in water released into the sea. And with rapidly growing populations, this will become an increasing problem in Pacific islands

Sewage may be treated, but this is expensive and requires areas of land for the construction of ponds. Most towns in Pacific Islands rely on the use of septic tanks - underground tanks in which the organic matter in sewage is decomposed through bacterial activity.

However, whether treated or untreated, sewage released into the sea will tend to increase the quantity of nutrients, particularly nitrates and phosphates, in the surrounding water.

High nutrient levels encourage the growth of marine plants and "blooms" of phytoplankton. As the plants eventually decompose they use up the available dissolved oxygen, which may be reduced to such low levels that fish and other marine species suffocate and die. Water affected in this way is said to be eutrophic.

High levels of nitrates and phosphates in lagoons and fringing reef areas result in the overgrowth of marine algae such as *Sargassum* (see Figure 3.3) a species that causes extensive coral destruction by abrasion and shading. High levels of nutrients may also change the structure of marine communities – one effect, for example, is that more types of herbivorous fish are attracted in by the plant growth.

Escherichia coli (E. coli) is a bacterium commonly found in human intestines, and its presence in water is used as an indicator of contamination by sewage. Many localised areas in Pacific Islands have recorded high levels of the bacterium. In Ela Beach in Port Moresby, for example, levels have been sufficiently high to constitute a health hazard and the beach has been declared unsafe for swimming.

In many low islands drinking water is obtained from an underground pocket of freshwater that floats on top of sea water. This freshwater lens, which represents a vital source of drinking water in many islands in the Pacific, can become contaminated by human waste when sewage disposal is inadequate. In many Pacific islands groundwater is becoming unsafe to use as drinking water without first boiling it. Poor sanitation and contaminated water were believed to be contributing factors in outbreaks of diarrhoea and in causing infant deaths in Kiribati. One solution is to collect rainwater from roofs, channeled through guttering into tanks.

Nutrients from groundwater may leach out onto fringing reef flats causing eutrophication. In some countries attempts are being made to counteract this – in Fiji, for example, thousands of coconut seedlings have been planted along some parts of the coast to absorb some of these nutrients.

Wastes from farming operations are also a concern in some areas. In the Federated States of Micronesia authorities are concerned about the effect of wastes washing into coastal areas from pig-rearing operations. Pig wastes, besides being a threat to the marine environment, are a risk to human health. A particular strain of *E.coli* from pigs can transmit gastroenteritis to humans and cause deaths in infants.

Problems caused by the disposal of sewage have encouraged many countries to experiment with waterless or composting toilets. These toilets convert human faeces into safe organic solids that can be used as a fertiliser on garden crops. Their widespread use would significantly reduce the growing problem with waterborne diseases and eutrophication.

Wastes, hazardous chemicals and oil

The oceans, because of their huge size, have been regarded as convenient places for the dumping of waste material. Wastes dumped in oceanic waters by industrially developed countries have included dangerous chemicals and radioactive material. Island governments have been responsible for dumping town and factory wastes, hazardous chemicals and oil at the sea's edge.

Discarded packaging including cans, bottles and plastic represents a problem in many island countries, even in towns that have set up garbage collection systems. Besides producing visual pollution on coastlines, even relatively inert material, such as plastic packaging, has an effect on marine life. Plastic bags may be mistaken for food by turtles, plastic can holders can choke sea birds and discarded plastic webbing can entangle crustaceans and fish.

The importation of used and often sub-standard motor vehicles by Pacific islands is believed to be a major source of waste materials and pollutants – particularly used oil, paint residues, and heavy metals. Derelict car bodies are also a widespread problem.

Many communities and towns have set aside rubbish dumps but their position and the increasing volumes of waste causes severe problems. Rubbish dumps tend to be built on the coast. As waste builds up it often encroaches into mangrove or lagoon areas where liquids and soluble material are leached into the sea.

In many Pacific islands the problem of rubbish disposal is severe. In Fiji, for example, a rubbish dump in Lami is believed to be leaching a variety of pollutants into Suva Harbour. And, in the Northern Mariana Islands, a rubbish dump in Saipan is claimed to be the most pressing of all environmental problems on the island.

In large islands rubbish dumps can be placed inland in areas with low rainfall to avoid leaching. But this is not possible in most small islands. The problem of rubbish disposal is more severe in cases where underground water is used, via springs or wells, by local communities. In these cases, there is the possibility that toxic material from rubbish dumps may leach out and contaminate underground water.

Atoll countries with very little land area have particular problems with waste disposal. In the atoll island of Funafuti in Tuvalu, for example, the “borrow-pits” constructed during the Second World War are badly polluted with rubbish and waste material.

Recycling materials in Pacific Islands is difficult but some efforts are being made. Local breweries in Fiji and Samoa are re-cycling glass bottles. In Rarotonga, Niue and Kiribati aluminium cans are collected and crushed before being exported for reprocessing.

Action taken by individuals can assist with reducing the amount of waste generated by communities. Waste will continue to be excessive as long as people continue to demand unnecessary packaging, insist on plastic shopping bags, and to use disposable containers for meals. The use of disposable diapers has greatly increased the amount of unsightly and unhygienic waste left on beaches and in rivers.

Several types of industries including mines, sugar mills, engineering plants, fish factories and fruit processors discharge their wastes directly into coastal waters. Wastes from some fish processors and tuna canneries, for example, have caused problems in several areas, notably in American Samoa, and in Fiji. Such wastes add large amounts of nutrients to the sea causing eutrophication in a similar way that sewage does.

Heavy metals such as copper, zinc, lead and mercury are dangerous pollutants. Some of these metals are particularly so because they are cumulative - that is, even small amounts ingested with food material will, over a long period, build up to high concentrations in the organs and flesh of marine animals. Larger carnivorous fish, may gain even higher concentrations by biomagnification though the food chains, and become extremely toxic to human beings (see biomagnification in Section 5).

Heavy metals from motor vehicles are mainly derived from engine wear and the disposal of batteries. Lead, sometimes stripped from discarded batteries for use as fishing sinkers, is a serious marine pollutant.

Pesticides are poisons used to kill or control pests - organisms that are considered harmful. Those which are used to kill weeds are called herbicides, and those used to kill insects are called insecticides. Problems occur when pesticides are washed away by rain into rivers and coastal waters.

Some pesticides are very stable - that is, they remain unchanged in the environment for a long time. Pesticides in water are particularly harmful to the young or larval stages of marine species. Some pesticides can also become concentrated in the flesh of high level carnivorous fish by the process of biomagnification (see Section 5).

The use of some particularly dangerous pesticides has been banned in many large industrial countries, but is still allowed in some smaller countries. Other islands that have banned the use of such pesticides have stockpiles of hazardous agricultural chemicals that are awaiting a safe method of disposal.

Other chemicals that are harmful to marine organisms are those used in antifouling paints. Antifouling paint is used to prevent the growth of marine species on the hulls of ships, and its effectiveness relies on an ability to leach out poisonous material at a low rate.

Antifouling paints usually contain metals in forms that are toxic to marine creatures, and one of the most effective ones is tributyl tin or TBT. But TBT is too effective and poisons marine life well away from the antifouled boat. Concentrations as low as one part in a thousand million of water have been found to kill molluscs or interfere with their reproduction. These days, the use of TBT is banned in all enlightened countries but unfortunately not worldwide. Tankers and freighters, particularly those flying under foreign flags of convenience, may still use the dangerous paint.

In the Pacific, the use of marine antifouling paint is a serious problem in harbours with a high density of shipping. Suva Harbour has had the unfortunate distinction of having water with the highest recorded concentration of TBT.

Mercury rising

Methyl mercury is accumulated and stored within the fat of predatory marine fish. Because of the concentrating effect within food chains (see Section 5), mercury levels are higher in top carnivores including sharks, tuna, marlin and swordfish. Marlins have been recorded with levels of mercury in their flesh of over 16 parts per million (ppm) whereas the internationally approved limit is 0.5 ppm.

Because mercury accumulates, larger fish are likely to contain more mercury. Hence it has been made illegal in some countries to market sharks larger than a certain maximum length. Canneries keep mercury levels within legal limits by mixing smaller tunas (skipjack tuna and small yellowfin) into cans of larger tunas.

Interestingly, high mercury levels have been found in old museum specimens of fish, suggesting that its presence is not a result of modern industrial pollution. Most mercury in seafood is derived from natural sources including habitats such as volcanic formations and islands.

To put the danger of mercury content into perspective, people would have to regularly eat quite a lot of large fish to be in danger. In addition, the risks must be weighed against the health benefits of eating fish. However, mercury from industry has been responsible for serious health problems. In Japan, people eating shellfish caught in Minimata Bay suffered from severe mercury poisoning, the effects of which included brain and genetic damage.

Oil and petroleum products can reach coastal waters when released by ships and certain shore installations. Perhaps the most common source of oil as a pollutant is from the disposal of used oil from motor vehicles. Large quantities of lubricating oil are imported into some islands – Tonga, for example, imports up to 40,000 litres of lubricating oil each month. Some Pacific island countries are attempting to establish centres to recycle used oil from motor vehicles.

Oil forms a thin film on the surface of the water and may cover and kill coral and other intertidal animals attached to rocks. Even minute quantities of petroleum products in the sea can cause seafood to become tainted with what has been called "kerosene taint". Villagers in Fiji, for example, have complained about such a taint in shellfish and other gleaned seafood due to spills from local petroleum distributors on Vuda Point.

Protecting the environment

Pacific island countries generally have one or more government agencies that are responsible for managing the coastal zone and marine resources. Most governments have legislation designed to protect the coastal environment through laws and regulations. In many cases, however, the regulations are weakened by not being strongly enforced.

In addition, many Pacific island countries have become contracting parties to various regional and international environmental conventions. One example is the "Convention for the Protection of the Natural Resources and Environment of the South Pacific Region, 1986 (SPREP Convention)." Countries that are signatories to such conventions have agreed, at least in principle, to take certain steps and actions to protect the environment.

Some island countries are now requiring public and private sector projects to include Environmental Impact Assessments (EIAs) before work can be commenced. An EIA is an assessment of the effects of a proposed development or activity on the environment and people. Projects, for example, such as the building of a new coastal road by the government and the building of a new coastal resort by a company would each require an EIA to be conducted and approved before the project is started. A completed EIA usually recommends one of three things – that is, that the project should either;

- proceed as planned (as it represents no threat to the environment),
- not proceed (as it represents an insurmountable threat to the environment), or
- proceed with certain modifications (as threats to the environment can be reduced),

The last of the three alternatives is perhaps the most common conclusion of EIAs – that is, certain actions or features must be included in the project in order to safeguard the environment.

In the examples used previously, the government may be required to lay large concrete pipes beneath the road so as not to restrict the tidal flow of seawater to stands of mangroves. The company building the new coastal resort could be required to include sewage treatment installations as part of the resort complex.

Actions for environmental protection

Although most Pacific countries have not yet implemented national coastal management programs, there are numerous initiatives at the national and local levels working to integrate government sectors and stakeholders. Many locally-based coastal initiatives throughout the Pacific are achieving success on a small scale. Specific program areas include:

- Marine protected areas (MPAs) and locally managed marine areas
- Policy and planning
- Monitoring coastal resources and uses
- Environmental education and training
- Water and sanitation
- Agriculture and forestry
- Supplementary incomes

Many of the problems that affect coastal ecosystems and marine life, such as overfishing and the degradation of inshore marine habitats, can be addressed at the community level.

People in communities, with government support, can take actions to protect the marine environment and conserve marine species. Traditional and modern protective rules made by communities are more likely to be effective as they are enforced by those with a direct interest in their continuation and success.

However, some environmental problems are complex and involve activities and areas beyond the control of a local community. For example, fish catches may be falling in a particular village because silt from a nearby river is killing the corals in its lagoon. Mangroves may be dying because a sea-front road has been built without proper planning. These effects may be caused by decisions and actions taken some distance from the village. Siltation, for example, may be the result of poor farming techniques or the logging of timber in hills many kilometres away from the affected village.

Complex and extensive environmental problems can only be addressed through an integrated effort by government and non-government agencies as well as community groups working together. This approach is known as Integrated Coastal Management (ICM).

Integrated Coastal Management (ICM) takes into account the inter-dependence of ecosystems and requires the involvement of many different agencies (for example, those responsible for agriculture, forestry, fisheries, public works and water supply) and other stake-holders. The involvement of communities is included under what is known as a "two-track" approach under which environmental problems are addressed from both the "top-down" and the "bottom-up" tracks.

The **"top-down"** track refers to the usual controls (laws and regulations) imposed by the national government and its institutions.

The **"bottom-up"** track emphasizes activities at the local community level that engage the local resource owners directly in management. The importance of community involvement is often reflected in the use of terms such as Community-Based Coastal Resource Management (CBCRM) and Community-Based Fisheries Management (CBFM).

In combining these approaches, activities include simultaneously working on (1) local-level, site-based management programs, with full involvement and ownership by local communities and (2) establishing frameworks and policies at the government level that provide links between local and national governments.

Growth in population sizes will continue to place pressure on Pacific island coastal ecosystems and their resources. The coast is under increasing threat from housing and development and the sea that supports coastal ecosystems is being polluted by silt, chemicals and waste from towns, forestry, agriculture and industry.

These are the problems that must be addressed urgently by local communities as well as by governments, non-government groups and regional organisations. Not to address these problems now will result in us handing on to future generations overcrowded countries with polluted water, degraded coral reefs and eroded bare landscapes in which there is insufficient seafood and a poor quality of life.

14. Glossary of terms and acronyms

Antifouling paint: a paint that leaches out poisonous material at a low rate to prevent the growth of marine species on ship's hulls.

Artisanal Fishery: a small-scale, low-cost, and labour intensive fishery in which the catch is consumed locally.

Bacterium (plural = bacteria): one of a large group of microscopic, single celled organisms, most of which are crucial to life on earth and some of which can cause disease.

Bilateral and Multilateral Agreements: an arrangement whereby foreign fishers pay a fee for access to fish stocks not fully utilised by national fishers.

Biodiversity (biological diversity): the variety of living material in terms of genes, species and ecosystems within a given area.

Biomass: the sum of weights of individuals in a stock or population of marine species.

Brackish water: a mixture of sea water and fresh water (as occurs near the mouths of rivers).

Calcium carbonate: the white limestone material which makes up the skeletons of coral polyps and the shells of molluscs; the chalk used on blackboards is mostly calcium carbonate.

Carnivore: an animal which eats another animal.

Catch Quota: the maximum catch permitted to be taken from a fishery; such a limit applied to the total catch from a fishery is often referred to as a global quota (as distinct from an individual quota).

Closures (in fisheries): the banning of fishing either during particular times or seasons (temporal closures), or in particular areas (spatial closures), or a combination of both.

Colony (in biology): a community of animals or plants of one kind forming a physically connected structure or living close together.

Co-management (cooperative management): arrangements between government representatives and user groups to take responsibility for, and manage, a fishery resource and/or its environment on a cooperative basis.

Community-based fisheries management (CBFM): arrangements under which a community takes responsibility for managing its adjacent marine environment and species.

Compost: Decomposed organic matter that can be used as a fertiliser on gardens.

Composting: The decomposing of organic matter by aerobic bacteria.

Coral polyp: a small individual coral animal with a tube-shaped body and a mouth surrounded by tentacles.

Critical habitats: habitats which are crucial in the life-cycle of marine species; typically, nursery and spawning areas, such as estuaries, mangroves, seagrass meadows and reefs.

Customary Marine Tenure (CMT): legal, traditional or de facto control of areas of water by indigenous people.

Demersal: living on, or near, the sea floor.

Ecologically Sustainable Development (ESD): development based on the sustainable use both of species and ecosystems, the maintenance of essential ecological processes, and the preservation of biological diversity.

Ecology: the study of the relations of organisms to one another and to their physical surroundings.

Ecotourism: tourism directed towards, and intended to support conservation efforts for, natural environments that may be threatened.

Environmental Impact Assessment (EIA): the assessment of the effects of a development or activity on the environment and people.

Escherichia coli (E. coli): a bacterium commonly found in the intestines. Its presence in water is used as an indicator of contamination by sewage.

Estuary: the wide tidal mouth of a river.

Eutrophic: (of a body of water) so rich in nutrients that it encourages a dense growth of plants, the decomposition of which uses up available oxygen and therefore kills animals.

Exclusive Economic Zones: an area of sea out to 200 nautical miles from coastlines or outer reefs, in which an adjacent country has control and responsibilities.

Extinction: the total disappearance of a species.

Fisheries regulations: controls designed to either restrict the amount, or efficiency, of fishing (input controls), or to restrict the total catch (output controls) to predefined limits in a fishery.

Freshwater lens: A pocket of freshwater that floats above sea water beneath small islands.

Greenhouse effect: the trapping of the sun's warmth at the earth's surface caused by high levels of carbon dioxide and other gases that allow the passage of incoming solar radiation but reduce the amount of reflected radiation.

Herbivore: an animal that eats plant material.

Integrated Coastal Management (ICM): coastal management that takes into account the inter-dependence of ecosystems, with the involvement of many different agencies and other stake-holders.

Larvae: the young stages of many marine animals including corals; most larvae are small and drift in the sea before becoming adults.

License limitation: the restriction of fishing to those people, fishing units or vessels holding licenses in a fishery.

Marine Protected Area (MPA): a marine area protected from uncontrolled human access and use by the application of various restrictions on activities, development and exploitation.

Minimum legal size: a regulation in which captured individuals smaller than a prescribed minimum size must be returned to the sea.

Minimum mesh size: the smallest size of mesh permitted in nets and traps; imposed on the basis that smaller individuals will escape unharmed.

Nutrients: in the context of the marine environment, dissolved food material (mainly nitrates and phosphates) used by plants.

Overexploitation: the situation where so many fish are removed from a stock that reproduction cannot replace the numbers lost.

Pelagic: living in the surface layers of the sea.

Photosynthesis: the process by which plant material is formed from water, nutrients and carbon dioxide using energy absorbed from sunlight.

Phytoplankton: small plants, which drift in the sunlit surface layers of the sea.

Predator: an animal that hunts another (prey) species.

Primary producers: plants, including algae and phytoplankton, which use sunlight and nutrients.

Property Rights: a degree of resource ownership by an individual fisher, group or community.

Quota: a limit on the weight or number of fish which may be caught in a particular stock or area.

Recruitment: the addition of young or juvenile animals to a fishable stock.

Septic tank: an underground tank in which the organic matter in sewage is decomposed through bacterial activity.

Sewage: waste matter, particularly human faecies and urine, conveyed in sewers which are part of a sewerage system.

Species: a distinct group of animals or plants able to breed among themselves, but unable to breed with other groups.

Stake-holders: the different people, groups, communities and organisations that have an interest in a particular activity, resource or area.

Subsistence fishing: the catching of fish to eat rather than to sell.

Symbiosis: a relationship between two different creatures which live together for the benefit of both. Plant cells (called zooxanthellae) have a symbiotic relationship with coral polyps.

Tributyl tin (TBT): a constituent of antifouling paint that kills marine animals or interferes with their reproduction. The use of TBT is banned in many countries,

Tsunami: a long high sea wave (or series of waves) caused by underwater earthquakes or other disturbances.

Upwelling: the vertical movement of water from the depths up into the surface layers of the sea.

Zooplankton: small animals, or the larvae of larger animals, which drift in the sea.

Zooxanthellae: small plant cells living within coral polyps and the mantle of giant clams.

15. References and further reading

Illustrations and information contained in this handbook were taken or adapted from the following publications.

Crennan, L. 2002. A synopsis of information relating to waste management, pollution prevention and improved sanitation with a focus on communities in the Pacific islands region. In Wright, A. and Stacey, N. (eds.) IWP Technical Report 2002/03. Vol.3.

Dalzell, P. 2002. A synopsis of information relating to sustainable coastal fisheries. In Wright, A. and Stacey, N. (eds.) IWP Technical Report 2002/04. Vol.4.

Falkland, T. 2002. A synopsis of information relating to the quality of freshwater and watershed management issues in the Pacific islands region. In Wright, A. and Stacey, N. (eds.) IWP Technical Report 2002/02. Vol.2.

Huber, M. 2002. A synopsis of information relating to marine protected areas.. In Wright, A. and Stacey, N. (eds.) IWP Technical Report 2002/01. Vol.1.

King, M.G. & King, S.A. 1996. The Oceans and Coastal Areas and their Resources. UNESCO-UNEP International Environmental Education Programme UNESCO, Paris. 99p.

King, M.G. & Lambeth, L. 2000. Fisheries Management by Communities; a manual on promoting the management of subsistence fisheries by Pacific Island communities. Secretariat of the Pacific Community. New Caledonia. 87 p.

King, M.G. 1988*. Coral reefs in the South Pacific. South Pacific Regional Environment Programme, South Pacific Commission, New Caledonia. 40p.

King, M.G. 1989*. Coastal environments in the South Pacific. South Pacific Regional Environment Programme, South Pacific Commission, New Caledonia. 40p.

King, M.G. 1995. Fisheries biology, assessment, and management. Fishing News/Blackwell Scientific Books. Oxford, England. 341 p.

Lal, P. 2002. Economic considerations in community-based project planning and implementation. In Wright, A. and Stacey, N. (eds.) IWP Technical Report 2002/05. Vol.5.

SPREP 1999. Coastal Management Profiles; a directory of Pacific Island governments and non-government agencies with coastal management related responsibilities. South Pacific Regional Environment Programme. 205 p.

Whyte, J. 2002. A review of lessons learned and best practice in integrated coastal watershed conservation and management initiatives in the Pacific islands region. In Wright, A. and Stacey, N. (eds.) IWP Technical Report 2002/06. Vol.6.

Wright, A. and Stacey, N. (eds) 2002. Issues for community-based sustainable resource management and conservation: considerations for the strategic action programme for the international waters of the small island developing states (six volumes listed separately herewith).

---

* these two previous SPREP publications are out of print and are replaced by this present handbook

16. Sample assignments for teachers and students

Assignment 1:
Prepare a list of depleted marine species in your country or community. To obtain information, talk to older people in local communities, to fishers and to government officers working with fisheries or the environment.

Assignment 2:
Review the status of a particular commercial fishery important to your country. In your review you should consider the status of the resource (under-exploited, fully exploited, or over-exploited) and whether rules and regulations applied to the fishery are effective.

Assignment 3:
Map the distribution and areas of mangroves, seagrass beds or coral reefs adjacent to your town or community. Talk to older people to discover whether these areas are increasing or decreasing. What changes have occurred and why?

Assignment 4:
To which regional and international environmental conventions is your country a contracting party? For example, is your country a party to the Convention for the Protection of the Natural Resources and Environment of the South Pacific Region, 1986 (SPREP Convention)? List the conventions to which your country belongs and list any actions or activities taken in relation to these conventions.

Assignment 5:
Review government legislation that seeks to protect the coastal environment in your country. Do you think that the relevant laws and regulations are being enforced? What more could be done?

Assignment 6:
Review the most serious threats to the coastal environment in your country. What actions are being taken, or should be taken, to counteract these threats?

SPREP

from mangroves to coral reefs

sea life and marine environments in Pacific islands

Michael King

ICRAN International Coral Reef Action Network

SOUTH PACIFIC OCEAN DEVELOPMENT CANADA C-SPOD

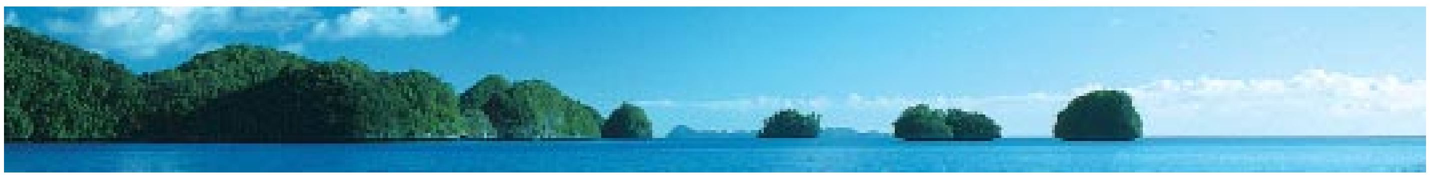
This handbook is about marine and coastal ecosystems in the Pacific islands region. Spread out over the world's largest ocean, these island countries have small areas of land, large areas of sea and populations that, in many cases, are increasing.

People exploit many of the living and non-living components of these ecosystems people. Wetlands are drained and filled in for housing, mangroves are cut down for firewood, sand is mined for making cement, coral blocks are used for buildings and a wide range of marine species is used as food.

In the past, people in local communities conserved the coastal environment and seafood stocks. But increasing populations, money-based economies and commercial fishing are replacing these traditional methods of management.

The first sections of this handbook describe some of the ecosystems common in the region - wetlands, mangrove forests, sandy shores, seagrass meadows, lagoons and coral reefs. Later sections describe some of the living things that are components of these ecosystems and the threats to the ecosystems themselves.

South Pacific Regional Environment Programme



Spine text

From mangroves to coral reefs

Michael King

SPREP