FISHERIES MANAGEMENT

AN INTRODUCTION FOR COMMUNITY AND VILLAGE USE

Student resource manual 1

CFMDP community-based management training programme

PNG NATIONAL FISHERIES AUTHORITY
COASTAL FISHERIES
Management and Development Project
ASIAN DEVELOPMENT BANK

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This manual has been prepared for the Coastal Fisheries Management and Development Project (CFMDP) by the project's Community Fisheries Management Adviser, Lyn Lambeth. The contents have been drawn from a variety of sources, both published and unpublished, including work of the Community Fisheries Section of the Secretariat of the Pacific Community, the University of the South Pacific's Marine Studies Programme, The Pacific Regional Environment Programme, and the Samoa Fisheries Division. Written sources are listed in the bibliography at the end of the manual.

The manual was prepared as a learning resource for CFMDP training courses in fisheries management, hosted at the National Fisheries College, Kavieng, New Ireland in October 2004 and September 2005. The course was primarily delivered by Lyn Lambeth with various inputs from other CFMDP advisers including Joel Opnai, Peter Watt, Garry Preston, Gerald Moore and John Aini.

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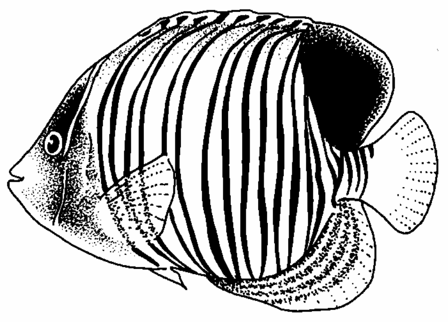


1 BACKGROUND

The National Fisheries Authority (NFA) underwent a reorganisation process from 1999–2003. As part of the reorganisation, provincial and lower-level government (LLG) agencies were given greater responsibility for the development and management of inshore fisheries resources. This approach was intended to:

- build natural resource management capacity at provincial and local government levels;
- improve the effectiveness of fishery management arrangements through greater stakeholder participation in the management process;
- meet NFA's obligations under the Organic Law to provincial and LLGs, which requires central agencies to devolve responsibility for natural resources development and management to lower levels of government;
- provide revenue-raising opportunities for provincial and local governments; and
- free NFA of primary responsibility for managing numerous and dispersed local fisheries, which NFA is not equipped to do.

The PNG Coastal Fisheries Management and Development Project (CFMDP) is currently addressing some of these goals.

The CFMDP is implemented through NFA with funds from an Asian Development Bank concessionary loan. The overall aim of the project is to reduce poverty in PNG's coastal communities by promoting the sustainable commercial use of inshore fishery resources by small-scale fishers. At the same time, the project aims to increase the ability of provincial governments, LLGs, community groups, stakeholder groups and other non-governmental organisations to work together on developing and implementing management schemes for fishery resources and the marine environment.

To assist in devolving the responsibilities of the management of inshore fisheries resources from NFA to lower-level governments, the CFMDP supports the establishment of community-based management (CBM) arrangements and assists relevant stakeholder groups in having a greater involvement in the fisheries management decision-making process.

As a first step in supporting CBM arrangements, the CFMDP has developed a training programme for workers involved in community-based fisheries management. Training includes a three-week course on fisheries management and community-based management. The first week covers fisheries biology and management, and is supported by this student manual "Fisheries Management: An Introduction for Community and Village Use". The second and third week covers community-based fisheries management, which uses the manual "Community-based Fisheries Management: A Training Manual.

In addition to the student manuals, a support package for trainers has been developed for both sections of the course. The trainers' guides are intended to provide additional technical background information for local trainers who will be teaching these training courses.

The fisheries management and community-based management training has been developed and delivered by the CFMDP Community Fisheries Advisers, with assistance from project staff and other resource people.

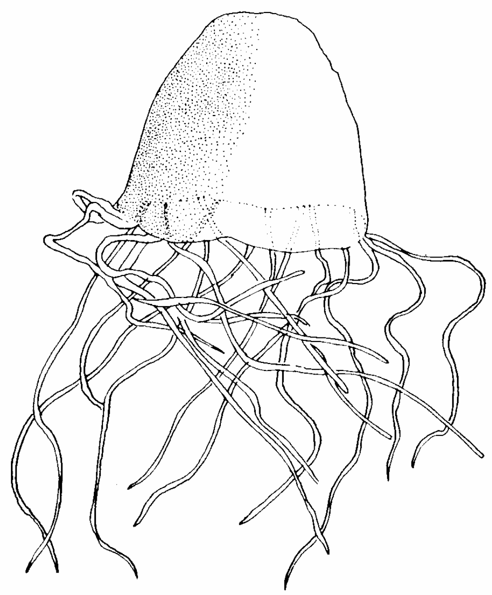
The **OBJECTIVE** of this course is to give participants a background in areas of interest and concern they are likely to encounter in a village or community during their work on community based fisheries management.

The course is *not* intended to make participants “experts” in all areas covered by this course. It focuses instead on building background knowledge of the principles of fisheries management in order for participants to gain confidence in working with communities in the promotion of community-based fisheries management. It is also designed to give participants the necessary knowledge to better understand the community management process, which is the substance of the second part of the course.

The overall intention of the fisheries management and community-based management course is to build capacity in effective promotion and facilitation of community-based fisheries management. The course does not include formal knowledge based assessment. There are no written or verbal tests or examinations and participants who complete the course will receive a Certificate of Attendance.

However, it is intended that persons who complete this course will have the confidence and a commitment to working as part of a team in the active facilitation of community-based fisheries management. The measure of individual success is active participation.

This manual is primarily an information summary. However, it also includes a series of activities that are meant to be undertaken in group exercises during the course. These activities have been designed to not only support the information in the manual, but to also give participants experience and confidence in public speaking and facilitating group meetings in the field.

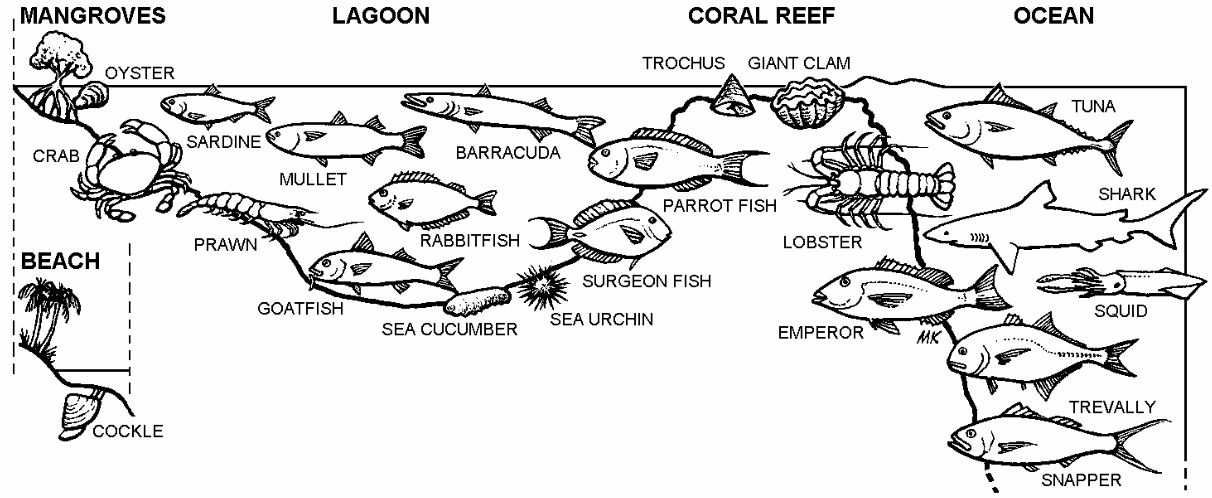


2 COASTAL ECOSYSTEMS – TYPES OF MARINE ENVIRONMENTS

2.1 Introduction

A community of living plants and animals, along with their surroundings, is referred to as an **ecosystem**. An ecosystem often takes its name from the most common, or most obvious, plant or animal present – such as a coral reef ecosystem or a mangrove forest ecosystem. There are many different types of marine environments, or ecosystems, in tropical islands. Many tropical islands have coral reefs that closely fringe the shore, while other islands have a sheltered lagoon between the shore and a barrier reef. Some of these islands have large river systems and mangrove forests that act as a barrier between the land and the sea. Beyond the coral reefs, the sea-floor rapidly drops away to deep water and the open sea.

Marine animals are specially adapted to living in particular environments. Marine ecosystems, while appearing to exist quite separately from each other, actually interact with each other. Many species migrate between different environments at different stages of their life-cycle; some fish, for example, grow up as juveniles in mangrove areas before migrating out to lagoons as adults. This is covered in more detail in the section on foodwebs and relationships between ecosystems.



A range of different environments, and some of the species present in each, are shown distributed along a profile of a tropical coastline.

Many of the living and non-living plants and animals in these marine ecosystems are used 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 animals are captured for food.

The use of coastal ecosystems requires sensible controls and regulations to avoid damage that is difficult, or even impossible, to reverse. The extent to which natural resources are renewable depends on a capacity to ensure that resources are not over harvested and that the environment on which these resources depend, does not deteriorate.

2.2 Coastal wetlands: estuaries and mangroves

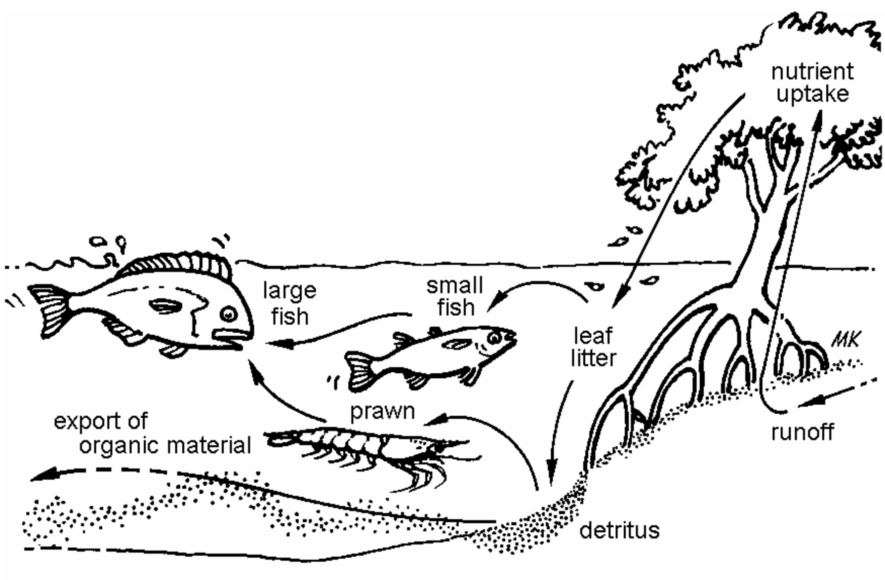
Coastal wetlands are places where plant communities are living in permanently wet areas. Wetlands are important ecosystems that support many different kinds of plants and animals. For many aquatic animals, wetlands are important nursery areas — areas where juveniles grow up before moving into rivers or out to sea.

Estuaries are places where rivers meet the sea. Here, the water is of low salinity, and is said to be brackish. As rain water washes across the land it picks up minerals and organic material. This material flows down the rivers to make estuaries, at the mouths of rivers. Estuaries are some of the most productive marine ecosystems.

Rivers often widen or branch into several outlets 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 river mouths (deltas).

Marine plants take hold in these rich banks and provide shelter and food for a large range of **herbivores** — animals that feed on plants and 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. In these ecosystems, there are often forests of **mangroves** — trees that are specially adapted for life at the sea's edge.

Mangrove forests are part of a productive ecosystem that supports abundant life through a food chain that starts with the trees. The leaves of mangrove trees, like all green plants, use sunlight to convert carbon dioxide gas to organic compounds in a process called **photosynthesis**. The carbon absorbed by plants during photosynthesis, together with nutrients taken up by plants from the soil, provides raw materials for tree growth. Tree growth is essential in sustaining the life of all other organisms that live in the mangroves. Live and decaying mangrove leaves and roots provide carbon and nutrients that are used by other organisms in the mangrove ecosystem.



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.

Nothing is wasted in a mangrove forest. Mangrove plants shed large numbers of nutrient-rich leaves that are either broken down by fungi and bacteria, or are eaten by small crabs that live on the forest floor. Decaying organic material breaks down into small particles (detritus) that are covered with a protein-rich bacterial film.

Detritus is the food source for many species of molluscs (snails), crustaceans (crabs, lobsters, shrimps and prawns), and fish, which in turn are the food source for larger animals.

Nutrients released into the water through the breakdown of leaves, wood and roots also feed the plankton and algae that form part of the mangrove ecosystem.

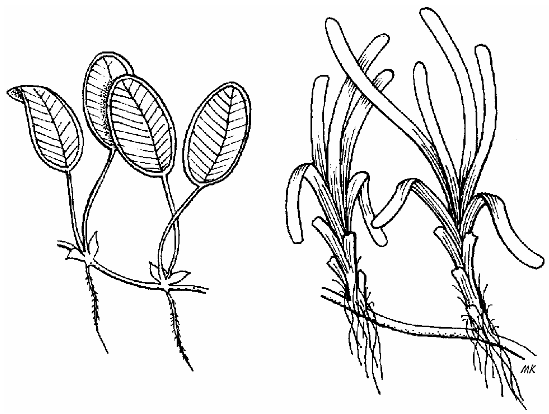
Mangroves play an important role in providing shelter and food for marine creatures. The juveniles of many different kinds of marine animals use mangroves as areas in which to grow (nursery areas) before moving out to deeper water.

Mangroves play an important role in preventing coastal erosion. Throughout the world mangrove forests have been cut down or destroyed, leaving low-lying coastal areas more susceptible to damage from cyclones and storm surges. By reducing the sea's current and trapping sediments, the tangled roots and trunks of the mangroves help to reduce siltation in adjacent marine habitats. Similarly, river-borne nutrients (including the agricultural chemicals present in many rivers) are likely to be trapped and recycled within mangroves.

2.3 Beaches and seagrass

Beaches are formed by particles of material washed ashore by waves and currents, or, in some cases, particles carried from the land to the sea by rivers. In tropical regions, most beaches consist of coral that has been broken up by storms into particles, or has passed through the digestive system of coral-eating fish such as parrotfish. In each case, coral skeletons are broken down to small particles that are carried by the sea's currents and deposited inshore to form beaches. Gently sloping beaches of sand prevent waves eroding and washing away the shore, and are, therefore, particularly important in low-lying areas. In coral atolls, beaches protect land that is often only a few metres above sea level.

In some shallow sandy areas there may be extensive underwater meadows of seagrass, which provide shelter and food for many different animals. Seagrasses also are habitat for fish and shellfish, and are nursery areas for marine animals that may live their adult life offshore. Seagrasses are similar to flowering plants on land, and unlike seaweeds (marine algae), they have root systems that are able to gain a foothold in drifting sand.

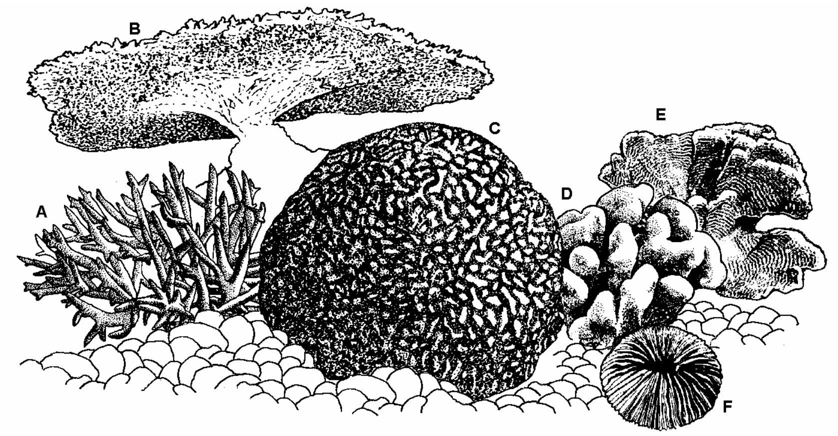


Sea grasses *Halophila* and *Thalassia*

Seagrass beds also perform the important physical functions of filtering coastal waters, dissipating wave energy and anchoring sediments. Seagrasses are often found near (and are ecologically linked with) coral reefs, mangroves, salt marshes and other marine habitats. Seagrasses are the primary food of dugongs and green sea turtles. Seagrass leaves decay to form detritus that is used as a food source by a wide range of marine animals.

2.4 Coral reefs and lagoons

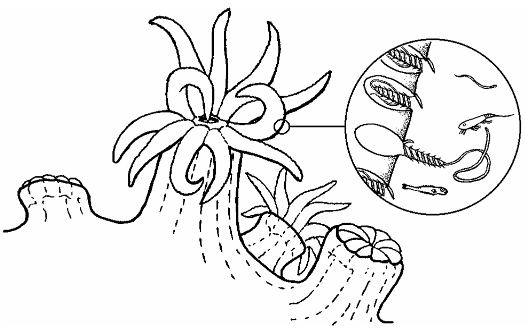
There are many hundreds of different types of coral. All corals are made up of small animals called polyps, which are usually less than 1 cm in diameter and live side by side in groups or colonies. A few species (types) of coral, such as the mushroom coral, have large solitary polyps up to 20 cm in diameter. Many coral polyps grow together as a colony to build a shared skeleton that has a particular shape depending on the species of coral.



A large number of coral colonies collectively form a coral reef, consisting of the skeletons of many millions of dead polyps. Living polyps are only found on the thin outer layer of the coral reef which continues to grow outwards and upwards with each generation. Coral reefs form one of the world's largest natural structures.

Some common types of hard, reef-building corals, including staghorn coral (A), table coral (B), brain coral (C), boulder coral (D), and leaf coral (E). Mushroom coral (F) exists as a single large polyp.

Coral polyps
Coral polyps are marine animals that are related to jellyfish and sea anemones. The polyp (shown below) has a tube-shaped body with a mouth surrounded by small arms or tentacles. In "hard" corals, the polyp produces a stony and cup-like skeleton of calcium carbonate (limestone) around its base. In most corals, each polyp retracts into its protective cup by day, and emerges at night to feed. If you use a diving mask at night, you will see that many corals are covered with a carpet of tiny feeding polyps.



Coral polyps – shown extended from their hard skeletons and, inset, stinging cells or nematocysts on a polyp tentacle.

Corals share with their relatives the jellyfish, 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.

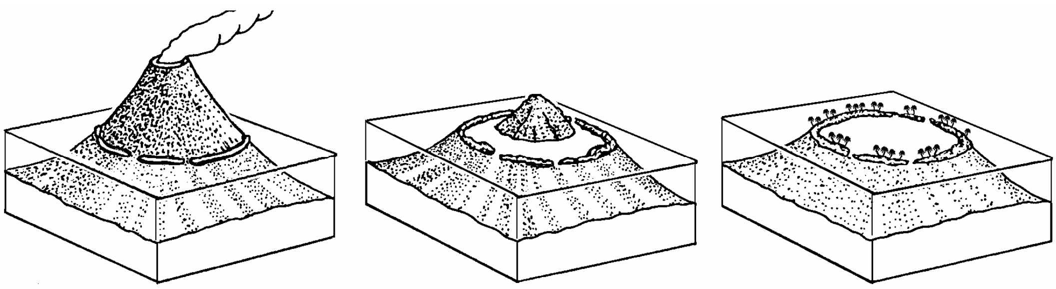
Besides capturing food that drifts in the water, coral polyps get their food from small plant cells (zooxanthellae) that live in their tissue. Through photosynthesis, the zooxanthellae use sunlight and dissolved nutrients to produce food that is shared with the coral. Thus, most corals, like plants, require sunlight and can only live in clear, shallow, sunlit waters.

Every year, for just a few nights in early summer, corals put on a spectacular display. In a brief, but highly coordinated spawning event, corals release millions of eggs and sperm bundles. At the sea's surface the bundles break apart and the sperm, with their tadpole-like tails, seek out the eggs. After fertilisation, the eggs hatch into **larvae** and the sea's surface is covered in a fine red dust of developing eggs and larvae. A larva is a tiny, swimming form of the animal. Larvae do not resemble the adult — a tadpole is a larva of a frog, a caterpillar is a larvae of a butterfly or moth — and must go through a major change, or **metamorphosis**, before they become adults.

The advantage of all individuals spawning at the same time is that the sperms have a greater chance of meeting eggs. Coral larvae drift on the surface of the sea for several days before sinking to the sea floor. Of all the larvae released by the parent corals, 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.

Types of coral reefs

There are three basic types of coral reefs – fringing reefs, barrier reefs and atolls. One explanation of how the different types of reefs evolve is based on the concept of an oceanic island gradually sinking over many thousands of years. As long as a newly formed island in tropical waters is within reach of drifting coral larvae, it soon acquires a fringing reef of coral. As the island slowly subsides or sinks, the fringing reef around the island actively grows upwards. Eventually a lagoon will form between the sinking island and the growing coral which then becomes a barrier reef. When the island sinks beneath the sea, the barrier reef maintains its upwards growth to become a circular atoll.



Types of coral reefs: from left, fringing reef, barrier reef and atoll.

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 on the sea floor that meets 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 eventually die leaving rock-like skeletons of calcium carbonate behind. New polyps eventually grow on top of the remaining skeletons, and 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 millions of polyps. One kilogram of coral rock may contain over 80,000 polyp skeletons.

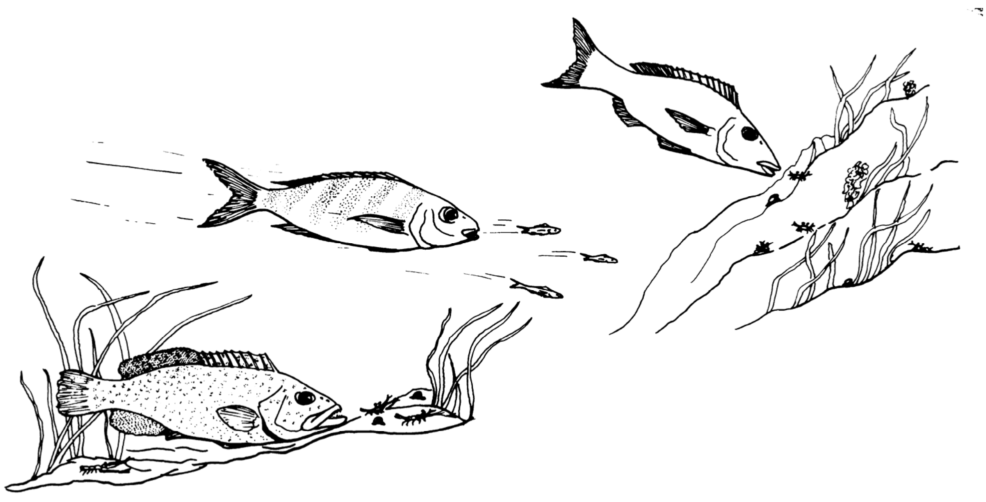
Although the growth of a coral is slow, the combined efforts of numerous polyps have produced some of the world's largest natural structures, including the Great Barrier Reef of Australia and the extensive barrier reefs of New Caledonia. A coral reef is part of a complex ecosystem and includes many animals and plants that are important food items for people living in coastal areas. In addition, coral reefs protect coastlines and villages, particularly from large ocean waves created by cyclones, and are the source of sand for beaches. Although corals have natural predators, such as the crown-of-thorns sea star and the parrot fish, the activities of people are the greatest threat to coral reefs.

On some tropical islands, corals are collected for sale as souvenirs or are used for building material. Harbour dredging and coastal building projects generally produce silt, which ends up in the water. This silt blocks off sunlight or smothers coral polyps, causing them to die. In some areas, corals are being destroyed by the use of poisonous chemicals and explosives for fishing. Coral reefs that have been destroyed by explosives are no habitat for fish, and the reef may not recover for many years. Recent studies indicate that it can take more than a century for a reef to recover by natural means once the live coral cover has been destroyed.

2.5 Outer reef slopes and the open sea

On the outer edge of coral reefs, the sea floor usually slopes down at a steep angle until the ocean floor is reached at an average depth of about three kilometres. After this the seafloor is relatively flat although it may rise to form seamounts and other island groups. In some areas the sea floor drops away to form very deep trenches (often over 10 km deep) such as the Tonga Trench and the Mariana Trench.

Many seafood species including spiny lobsters and fish such as groupers and snappers are caught on the outer reef slopes. But in the open ocean, there are no reefs to provide shelter or large plants to provide food, and only a few specialised types of fish, such as tuna, can live there. These oceanic fish wander over large areas of the ocean hunting smaller fish that feed on small drifting animals (zooplankton). The zooplankton, in turn, feed on very small, drifting plants (phytoplankton). Phytoplankton, however, can only grow where there are nutrients, mainly dissolved nitrates and phosphates. Most surface areas of the sea contain only small quantities of nutrients to feed phytoplankton, and can, therefore, support only small numbers of fish. An exception to this is a particular area where water moves up from the deep as an upwelling, bringing with it large quantities of nutrients.



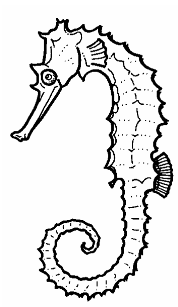
3 CLASSIFICATION OF PLANTS AND ANIMALS

3.1 What is a fish?

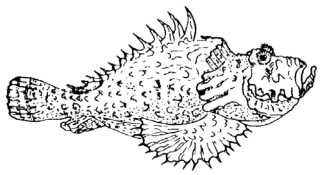
If you make a list all the defining characteristics of a fish, can you think of any of these characteristics that represent a fish and only fish? Can you think of any other animals that have these features, or can you think of some fish that don't?

What is a fish?	Make a list of some of the defining characteristics of a fish
1. 2. 3. 4. 5. 6. 7.	

Some unusual fish to consider:



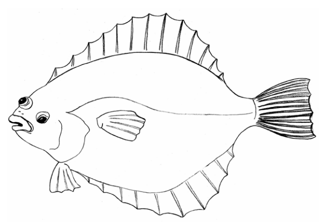
seahorses — unusual shape, inflexible body encased in bony rings, move slowly, catch prey by "suction" action of snout, males carry the fertilized eggs in a pouch;

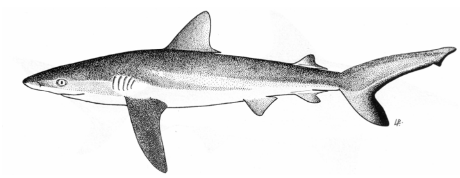


stonefish — no scales but warty skin glands covering body (including venom glands at base of dorsal fin spine), no swim bladder so it can sit on the ocean floor;

mudskippers — amphibious (can live in or out of water), modified pectoral fins for moving in water or on land, store water in gill chambers to keep them moist in the air;

flounder — flattened body with both eyes on the top, the larvae start off with one eye on either side of the body but as they grow the body flattens and one eye moves to the other side;





sharks — cartilage instead of bone, both the teeth and skin are actually modified scales, no swim bladder but has a large oily liver to give some buoyancy (sharks still need to keep swimming or they will sink).

Scientists sort living organisms into groups, to help them identify and study them. These organisms are given scientific names, much like a first and last name. A scientific name helps to:

- identify its relationship to other organisms;
- identify common ancestors; and
- avoid the confusion of common names and different languages.

Plants and animals are grouped together, or classified, according to how closely they are related, and on the basis of shared characteristics. The assumption is that the greater the degree of physical similarity, the closer the biological relationship.

A large group is broken down into smaller and smaller groups, starting with the largest unit, **kingdom**, such as plants or animals, down to the finest unit, **species**, such as the paddletail snapper, *Lutjanus gibbus*.

3.2 Vertebrates and invertebrates

In between **kingdom** and **species** are more groups based on shared characteristics, each of which serves to classify the plant or animal to a finer and finer level. For example, animals can first be divided into **vertebrates** (with a backbone) and **invertebrates** (without a backbone). All vertebrates have a backbone, but their other characteristics can be quite varied. Vertebrates are further divided into seven main groups: jawless fish, cartilaginous fish (sharks & rays), bony fish, amphibians, reptiles, mammals and birds. Those seven groups are divided into other groups, until the final classification is reached, species.

Jawless fish	Sucker-like mouth and rasping teeth, eel-like body, parasites or scavengers
Cartilaginous fish	Skeleton made of cartilage, small toothlike scales, no swim bladder, internal fertilisation
Bony fish	Bony skeleton, broad flat scales, swim bladder for buoyancy, mostly external fertilisation
Amphibians	Small lungs, some also breathe through skin, lay eggs with no outer covering or shell
Reptiles	Scales, usually lives on land, lays eggs with leathery covering
Mammals	Give birth to live young, have hair or fur, young feed on mothers milk
Birds	Feathers, usually can fly, lays eggs with a hard shell, has a beak

Invertebrates can be divided into seven main groups: flatworms, annelid worms, molluscs, crustaceans, cnidaria, nematodes, echinoderms. Here is a brief description of what each one looks like.

Flatworms	Worms with flat bodies
Annelid worms	Worms whose bodies are made up from segments
Molluscs	Soft bodies with slimy skin, usually within a hard shell
Crustaceans	Segmented body, jointed legs, hard skeleton outside the body
Cnidaria	Two layers of cells with jelly in between
Nematodes	Worms with no segments
Echinoderms	Spiny skin, body usually divided up into five sections

Each classification, or group, has a special term, starting with Kingdom, followed by Phylum, Class, Order, Family, Genus and Species. Two organisms that are very closely related to each other will have the same name all the way down the line, until the very last term, species. An example of this is the paddletail snapper, *Lutjanus gibbus*, and the blueline snapper, *Lutjanus kasmira*. Organisms that are not at all similar will start showing different names under the classification terms further up the line. See how the albacore tuna, *Thunnus alalunga*, starts differing from the two snappers at the Family classification. The sandfish, *Holothuria scabra*, starts differing right up at the phylum level, as you would expect, because a sea cucumber is nothing like a fish. At what classification do you think a plant would start showing a different name?

Classification	Example 1	Example 2	Example 3	Example 4
Kingdom	Animal	Animal	Animal	Animal
Phylum	Chordata	Chordata	Chordata	Echinodermata
Class	Bony fish	Bony fish	Bony fish	Holothuroidea
Order	Perciformes	Perciformes	Perciformes	Aspidochirotida
Family	Lutjanidae	Lutjanidae	Scombridae	Holothuriidae
Genus	*Lutjanus*	*Lutjanus*	*Thunnus*	*Holothuria*
Species	*gibbus*	*kasmira*	*alalunga*	*scabra*

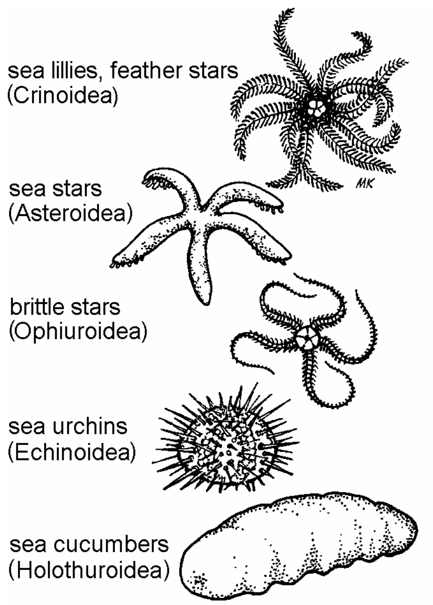
Each animal and plant ends up with two names (taken from Latin and Greek) to identify it – the **genus** name, and the species name. A genus is a higher level category that includes one or more species under it. A **species** is a group of organisms with similar features that are able to interbreed and produce fertile offspring. Each species in related groups share the same ancestors, but have evolved differently.

4 RESOURCE SPECIES

In spite of the large diversity of marine species, most species of animals used by people are found in one of four large scientific groups: three invertebrate groups and one vertebrate group. Species are included in a particular group 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 sections briefly describe some members of these groups – the ones that are important in fisheries of the Pacific Islands. Seaweeds (marine algae) are included because of their use as food in many islands, and their importance at the base of the food webs described in a later section.

4.1 Echinoderms

Echinoderms, including sea cucumbers and sea urchins, have a covering, or external skeleton, of hard plates. In sea cucumbers, however, these plates are reduced to small spikes embedded in the thick body wall. At least seven different species of sea cucumbers are used as food in the South Pacific; some of these are boiled, smoked and dried for export as beche-de-mer to Southeast Asia. Sea urchins are collected as food from shallow water lagoons and reefs, and the star-shaped reproductive organs are regarded as delicacies in many countries of the world. Starfish, brittle stars and feather stars are also classified as echinoderms.



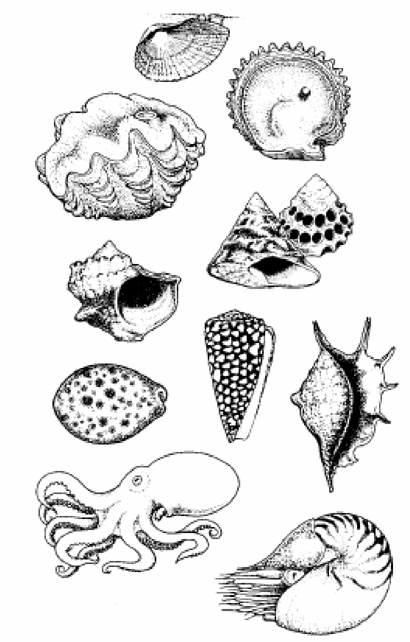
4.2 Molluscs

There are more than 65,000 different species of molluscs, and these include creatures as different as the giant clam and the octopus. Although most molluscs are encased in one or two shells, others have no shell at all. The three different classes of molluscs of commercial importance are the bivalves (such as clams), gastropods (including trochus shells) and cephalopods (such as octopuses and squids).

Bivalve molluscs (clams, cockles and pipis) have two shells. Most of these molluscs get their food by filtering phytoplankton from the surrounding water. Many species of bivalve molluscs (such as cockles and pipis) live under the sand, and pump seawater through two tubes, or siphons, which stick up through the sand. These molluscs are collected in village communities, particularly by women, and are an important source of seafood when the weather is too rough to fish in the open sea.

The world's largest bivalves — giant clams — live in clear, shallow water on coral reefs. Giant clams have been overharvested in many islands, and some species have become locally extinct in Micronesia and Melanesia. In Southeast Asia the dried muscles of giant clams are regarded as a delicacy. Pearl oysters, which may form pearls around grains of sand or other material that irritates their soft tissues, are grown commercially on some Pacific Islands.

Most gastropods (sea snails) have a single shell for protection, although some, such as sea hares (sea slugs), have no shell. Several different species, such as the green snail, are collected from rocky shores or reefs for use as food. Gastropods have file-like teeth, called radula. With the radula, some gastropod species scrape plant material from rocks, while other carnivorous species bore through the shells of bivalve molluscs. Trochus shells, which have a pearly inner lining, are collected and used in the manufacture of buttons. The sea hare, which grazes on algae and is collected for food, has a shell that is basically just an internal horny plate.



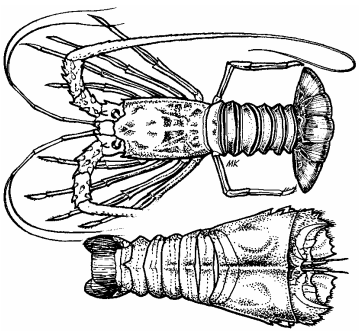
Because of their attractive shells, many different bivalves and gastropods are collected, mainly by women, for making handicrafts such as necklaces. Selling handicrafts contributes substantially to the incomes of many coastal communities.

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, cuttlefish and nautilus. Squids and cuttlefish have evolved for life in the open ocean and, squids in particular, are like jet-propelled rockets. The octopus, which is food on many islands, usually lives in holes on the coral reef and comes out at night to hunt.

The nautilus, whose shell is sometimes found washed up on reefs, lives in the deep waters of the Indo-Pacific. 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 the tropical waters of the eastern Indian Ocean and the western Pacific Ocean.

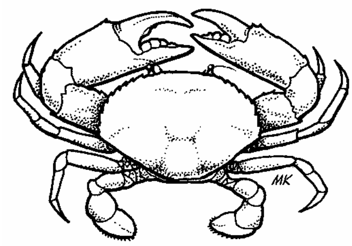
4.3 Crustaceans

Over 26,000 marine species, including prawns, shrimps, lobsters and crabs, together with such animals as barnacles, are called crustaceans. Crustaceans typically have a body covered with a hard shell (or exoskeleton) and jointed legs. In order to grow in size, the animal casts off (or moults) its hard exoskeleton and grows before a newly-formed shell hardens.

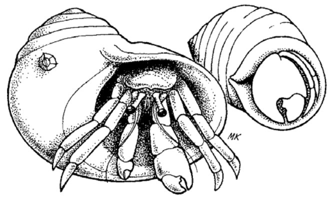


Spiny lobsters generally live on coral reefs and outer reef slopes, and are usually caught by divers using spears. After reproduction, the female spiny lobster carries fertilised eggs underneath her abdomen or "tail". The eggs hatch as small larvae that drift with the ocean's currents before settling on reefs to grow to adults. Slipper lobsters, which are related to spiny lobsters, are usually speared on sandy seafloors.

One of the larger inshore species of crab is the mud crab, which spends the early part of its life cycle in estuaries and mangrove areas. Many other smaller crabs are caught on rocky shorelines.

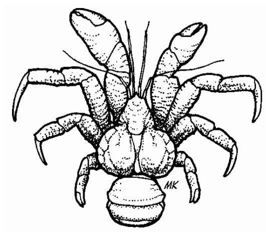


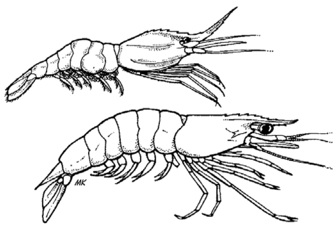
Like lobsters, female crabs carry eggs beneath their abdomens. The mud crab carries her eggs out to sea, where they hatch into larvae that drift back to inshore areas.



Hermit crabs fit their bodies inside empty sea shells. The crabs never kill the original occupants of the shells, and look for progressively larger empty shells as they grow. In some species, the larger of the two claws is used as a tightly-fitting trapdoor to the shell in which they live.

A relative of the hermit crab is the coconut crab, which is one of the largest of all crabs and spends most of its life on land. Its large size (up to 30 cm across the shell) prevents it from living in an empty gastropod shell like other hermit crabs. Only juvenile coconut crabs live inside shells like their hermit crab relatives.

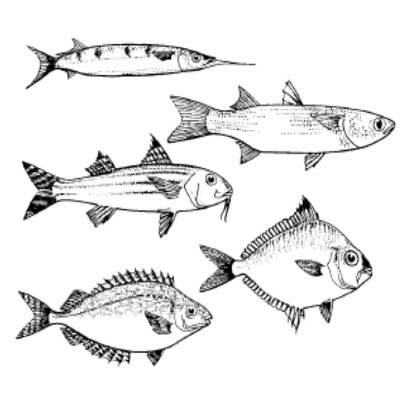




The names "prawns" and "shrimps" are often used interchangeably. However, there are two commercially important groups, penaeids and carideans. Most penaeid prawns (called shrimps in some countries such as the USA) produce juveniles that require brackish water nursery areas in which to grow. Hence, prawns 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 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 penaeid prawns 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 the rivers of many Pacific islands. Deepwater caridean shrimps have been found off many Pacific islands in depths of 600–800 m. However, catching shrimps in such depths is not viable economically.

4.4 Fish — inshore species



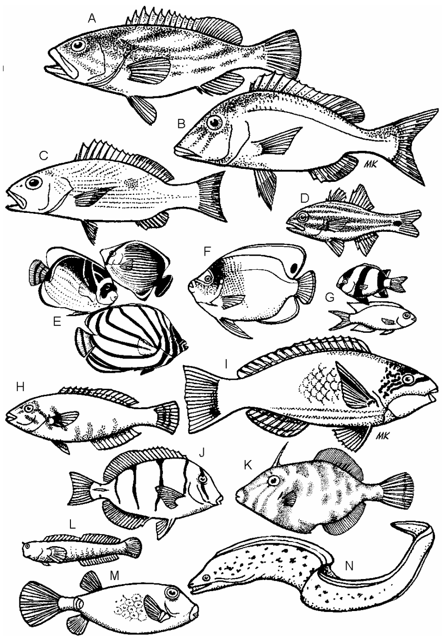
Of all the groups of animals with backbones (vertebrates), fish are the most numerous. There are over 25,000 different species of fish distributed in environments from high mountain pools to the deepest parts of the ocean. In most species of fish, the female releases eggs into the sea before they are fertilised by sperm from males. The fertilised eggs hatch into small larvae that are often planktonic and drift with ocean currents. After a period of time (which varies from species to species), the larvae change into adults that are either demersal (living near the sea floor) or pelagic (living near the sea surface).

Inshore fish species include (from the top) garfish, mullet, goatfish, ponyfish and rabbitfish.

Sheltered, inshore areas, particularly estuaries, are rich in food and are able to support a wide variety of fish species. Some fish species, including garfish, stay in inshore areas throughout their life cycle. Other species use sheltered inshore waters only during part of their life cycle, often as nursery areas in which the young grow up.

4.5 Fish — coral reef species

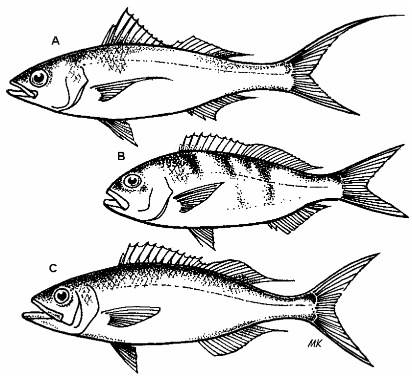
A coral reef ecosystem contains more species of fish than most other environments. Larger fish include the many different species of emperors, groupers and snappers. Smaller species commonly eaten include surgeonfish, parrotfish, wrasse, triggerfish and eels.



A) groupers, coral cods and coral trouts (Serranidae)
B) emperors (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)

Adult coral reef fish generally live within a small home range on the reef. They reproduce repeatedly over a lifespan of less than 10 years to produce pelagic larvae. Many coral reef fish, particularly trevallies, groupers and surgeonfish, produce larvae that drift far out in the ocean before returning and settling on coral reefs as adults. The species with the longest larval phases, have the greatest potential for dispersal and are widely distributed on isolated reefs across the Pacific.

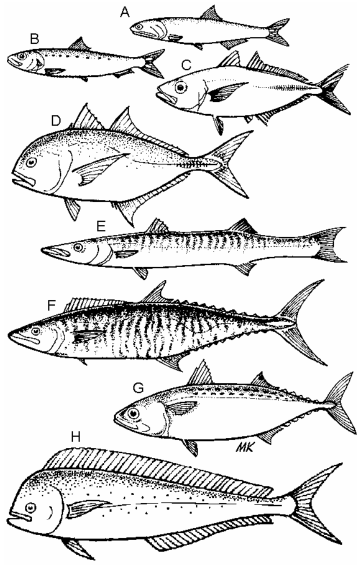
4.6 Fish — deepwater reef slope species



Beyond the coral reefs, many demersal species are caught on the shallow outer reef slopes. Deepwater snappers are caught by hook and line in depths of about 200 m on the steep slopes of islands and seamounts. These large deepwater snappers are valuable in tropical areas, as their distance from coral reef ecosystems means that they are unlikely to be affected by ciguatera, the toxic condition that seasonally affects some reef fish in shallower water. Deepwater snappers are potentially vulnerable to overfishing, and seamounts and reef slopes in parts of the Pacific have been overfished for these fish.

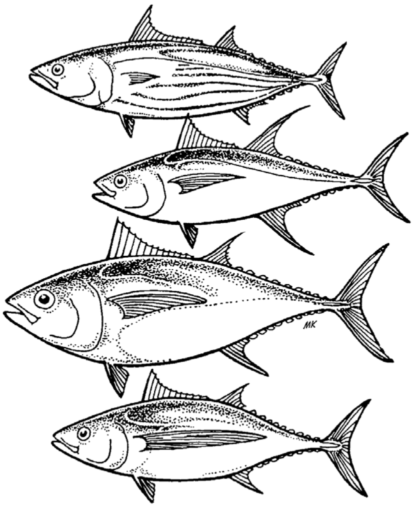
Tropical deepwater snappers A) *Etelis coruscans*, B) *Pristipomoides zonatus* and C) *Aphareus rutilans*

4.7 Fish — tunas and other pelagic fish



Inshore pelagic fish include the jacks or trevallies as well as the smaller horse-mackerels or scads, which form hunting schools on many reefs. In the western Pacific, the Indian mackerel is commonly netted in lagoons, and the Spanish mackerel is trolled off reefs. Barracudas are more widely distributed, and are voracious predators in the vicinity of coral reefs.

Right, pelagic fish: A) anchovies, B) sardines, C) scads, D) trevally, E) barracuda, F) Spanish mackerel, G) Indian mackerel, H) mahi-mahi



Further from the coast, in the open sea, the best known pelagic fish are the dolphinfish (dorado or mahi-mahi) and several species of tuna (shown on the left). Tunas are fast-swimming pelagic fish related to marlins and sailfish, and are distributed over large areas of the ocean. Tuna are caught by local fishers in many Pacific Island countries, often by trolling lures behind small boats. Commercial vessels use longlines and purse-seine nets to catch albacore, big-eye and yellowfin tuna. Approximately 35% of the world tuna catch is caught in the Pacific Ocean. 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 some species, such as skipjack tuna, may stay in one area for their whole lifespan.

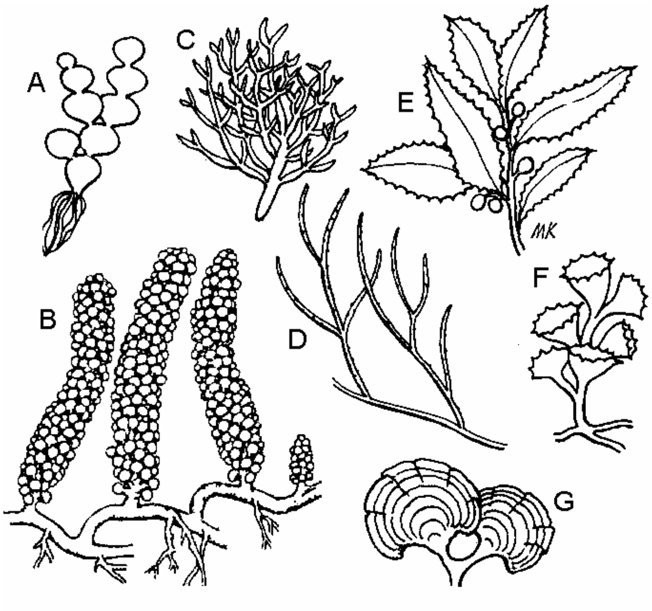
Tunas, from the top: skipjack, *Kasuwonus pelamis,* yellowfin, *Thunnus albacares,* big-eye, *Thunnus obesus* and albacore, *Thunnus alalunga.*

4.8 Seaweeds

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

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 green, red or brown algae. In tropical areas, there are fewer and less striking species of marine algae than there are in cooler waters. However, algae form the basis of many tropical food webs and, through the remarkable capacity of some species to retain calcium (become calcified), contribute to the coral reef mass. Although seaweeds are an important part of shallow-water marine ecosystems only a few species are commonly eaten in Pacific Island countries.



Green algae include the common reef species *Halimeda*, with its branched chains of flat segments that are often calcified and greyish in appearance. Green sea grapes, *Caulerpa racemosa*, are commonly collected by women for food from reef tops at low tide. Examples of red algae include the edible seaweed *Gracilaria* and the fleshy seaweed *Eucheuma*. The latter is farmed on floating ropes before being harvested, and then dried and processed to extract carrageenan and agar for use as food additives.

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

Brown seaweeds include funnel weed, *Padina*, which grows on dead coral, and the floating brown seaweed, *Sargassum*, which is one of the largest tropical algal species. One of the few edible brown seaweeds is the spiny top, *Turbinaria*, which can be boiled and eaten.

ACTIVITY: RESOURCE SPECIES

The purpose of this exercise is to get participants thinking about some of the many things they already know about the marine environment. Most coastal communities have a lot of knowledge about their marine environment that is often overlooked by outside agencies or marine resource experts. In this exercise participants will work as a group to identify and record as much information as possible about the marine environment, marine resources and any problems or potential problems. The information written down in this exercise will be used later in the course in the next group activity about responsibility, management controls, and solutions to problems.

Materials: Butchers paper or very large poster paper, coloured pens or pencils, tape, notepads and pencils

Split up into small groups of 4 or 5 for this exercise. Appoint one person in the group to be a recorder. It might be best to record everything in a notebook first, then at the end of the exercise sort out all the information onto the large sheet of paper using textas. The table below shows an example of a format to follow. Appoint another person to be responsible for giving a presentation on the group's information to the rest of the class at the end of the exercise.

Task: Each group is to make a list of the main types of fishing gear used and the marine resources that are caught or collected by people in your community. Note down who is mainly responsible for harvesting this species. For example, hand collection of shellfish may be practised mainly by women and children, and offshore fishing for tuna by men. Consider problems associated with the fishing method or species, and list what those problems might be.

Finally make a note of any other observations about the marine environment and any problems presently affecting it. Discuss other activities that affect the environment.

species/fishery	gear/methods	who harvests?	problems?
e.g. lobster	hand or spear	men	no more big ones left

other observations: corals dying in front of village, lots of rubbish on beach.

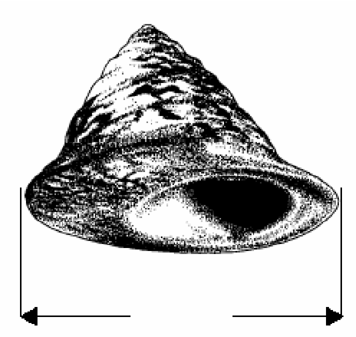
Discussion and presentation

A representative from each group is to pin up their finished chart and give a presentation to the rest of the class. Keep the charts as they will be used again later in the course.

5 FISH AND INVERTEBRATE BIOLOGY

5.1 Size at first maturity

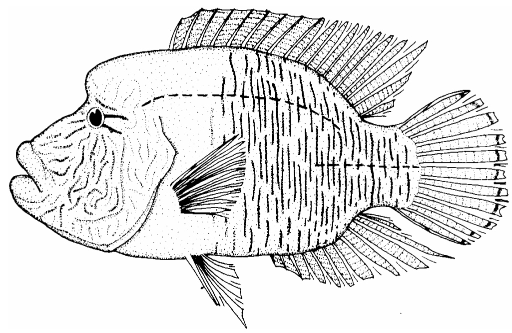
To understand the need for fisheries management, marine environmental protection, and the reasons behind controls or regulations on fisheries activities, it helps to understand a little about the biology and reproductive characteristics of fish, shellfish and other marine life. This section of the manual looks at fish and invertebrates, and what they need to live and reproduce.



Fish and invertebrates are like humans in that they must reach a certain age and size before they are physically mature enough to start breeding. The size and age will differ for different species, even for quite similar species. Scientists can study the reproductive characteristics of a particular species and estimate at what size, on average, that species will start reproducing. This is called **size at first maturity**. These estimates are what many minimum size regulations are based on.

For example, scientists have studied some of the fish species important to the live reef food fish (LRFF) trade and estimated the size that each species needs to reach before it is mature enough to reproduce.

On average, the humphead Maori wrasse (*Chelinus undulates*) first starts reproducing when it is around 42 cm in length. The squaretail coral trout (*Plectropomus areolatus*) first starts reproducing when it is around 33 cm in length.



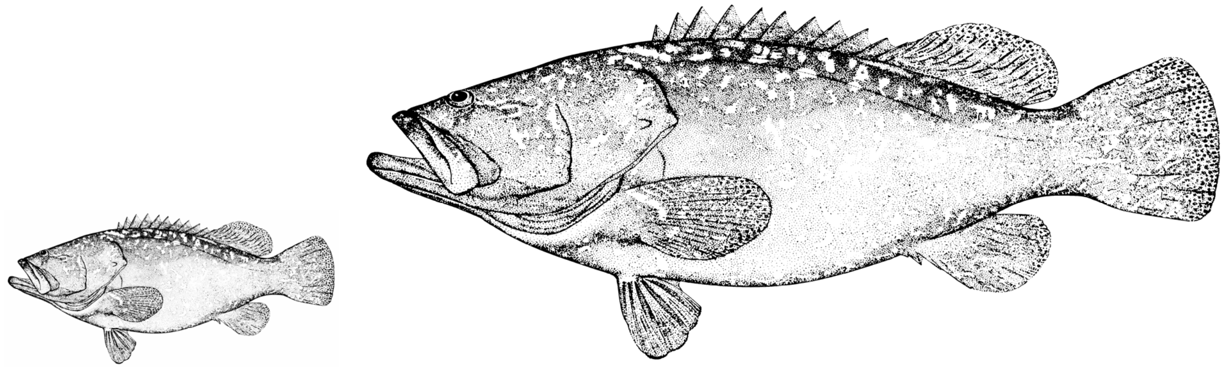
A 35 cm Maori wrasse, or a 25 cm squaretail coral trout, is still immature and will not have had a chance to reproduce.

The minimum size limit for Maori wrasse in PNG is 65 cm, allowing the fish to reproduce at least once before it is caught.

Many fish and invertebrates produce thousands or millions of eggs each time they breed, although very few of these actually make it through to maturity. Allowing each species to reach its **size at first maturity** before catching it gives the species a chance to reproduce and contribute to the continued growth of the population. Catching it before it is mature enough to reproduce means that particular individual will never add to the population. Imagine an island population of humans where every year the youths go away to study and never return. Eventually the population would be reduced to elderly people and very young children and, if the situation continued, the population would eventually die out because there would be nobody left to reproduce. This is what happens to a fish or invertebrate population where young individuals are continually removed before they have reproduced; eventually the remaining adults become too few to maintain the population and that fish population slowly dies out.

One area where fish and invertebrates differ from humans is that often, the larger and older the individual is, the more juveniles it is capable of producing. Once a young female fish or invertebrate has reached breeding age, the number of eggs it produces is often related to her size: larger females produce many more eggs than smaller ones.

For some species, if a female fish is allowed to double in size, the number of eggs she produces will increase **8** times. One study concluded that one large 12.5 kg grouper or snapper would produce the same number of healthy eggs as 212 fish of the same species weighing 1.1 kg each (and weighing, in total, 233 kg).



Maximum size regulations take advantage of this characteristic by protecting the largest, most productive breeding adults of a population.

Once an animal of a particular species has reached a certain size and age to start breeding it is ready to **spawn**, often at a particular time of the year or moon phase when all the other breeding individuals of that species are also ready. Many fish and invertebrates reproduce in a similar way: at spawning time the animals release sperm and eggs directly into the water where they mix. If the mixing is successful, the eggs become fertilised and develop into larvae, a tiny swimming form of the animal.

Each fish and invertebrate species has developed a successful reproductive strategy that allows it to survive in the highly competitive coral reef environment. Categorising those methods can become very complex when all the subtle variations that occur between thousands of different species are considered. The variation is a direct result of the diversity of the reef environment.

5.2 Reproductive methods

Fish and sharks have three methods of reproduction that are classified depending on how they care for their eggs. These three terms apply to both (a) where the embryos undergo development (i.e. inside the mother or outside in an egg), and (b) how parents provide nutrition for their embryos.

- **Oviparity —** fish lay undeveloped eggs, fertilisation can be external (90% of bony fish) or internal (some sharks and rays), there is no nutrition apart from the yolk.
- **Ovoviviparity —** there is internal development of the eggs *without* direct nourishment from the mother (only the yolk), eggs hatch and develop inside the mother, the young are advanced at birth (most sharks and rays) or larval birth (some rockfish).
- **Viviparity —** there is internal development of eggs with direct nourishment from the mother, the young are fully advanced at birth.

Advantages and disadvantages of oviparity

Oviparity is the way that the majority of fish and invertebrates reproduce. Some of the **advantages** of this method are:

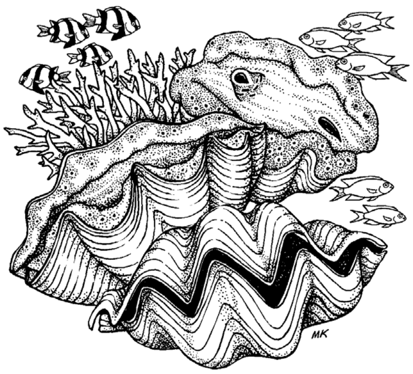
- The eggs are "inexpensive" to produce, meaning the parent doesn't have to supply nutrients to a developing egg or embryo. The energy saved by not supplying eggs or embryos can instead go into producing many eggs. The adult produces many offspring, which are broadcast into the **plankton** (tiny plants and animals that float freely in the water) to drift with tide and currents.

- When the offspring settle out of the plankton, they may be in totally new environments, allowing for a greater potential area for the young to survive in, and a greater potential for the species to spread.
- Because the eggs are in the water, they do not dry out (and therefore don't need a protective coating or shell like reptile or bird eggs do).

Oviparity also comes with its **disadvantages**

- When born, the fish must first go through a larval stage for growth before they transform into the adult stage. In this larval stage, they must fend for themselves in getting food and avoiding predators.
- They may not find a suitable environment when they settle out of the plankton column.
- The survival of individual eggs is very low, so millions of eggs must be produced in order for the species to ensure that enough eggs make it through to adulthood.

Hermaphrodites



Some fish and invertebrates are **hermaphrodites**, meaning they can be male or female, depending on the situation or stage of life. This gives them a better chance of finding a mate to reproduce with. Some species change from male to female, or female to male, at a particular time in their life. Other species can be male or female depending on the situation — they can release eggs or sperm while spawning. For example, giant clams in a particular area will spawn at the same time. The release of eggs from one individual triggers the release of sperm by another nearby individual.

In some species of fish such as groupers, individuals mature first as females and later become males. With clownfish it is the opposite, the male phase occurs first.

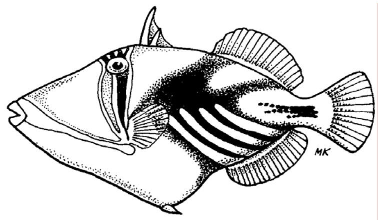
5.3 Reproductive methods of marine fish

Nearly all marine fish reproduce through the production of eggs that develop and hatch while exposed to the marine environment. There are exceptions though; many sharks and rays produce live young from internal incubation, but most marine fish (and invertebrates) produce through external fertilisation and, even if the eggs are protected by the parents until they hatch, the eggs are exposed to the marine environment. The eggs of most marine fish will float, and some species produce eggs that contain an oil droplet that enhances the egg's buoyancy, thereby allowing the dispersion of millions of eggs on the oceanic currents.

Some species fight this inherent buoyancy and attach and/or protect the eggs until embryonic development is complete and the egg releases a competent larva able to swim and feed right after hatching. Marine fish have been able to develop a wide variety of modes that adapt their eggs to the marine environment and ensure survival and dispersion of the young in ways best suited to survival of their species.

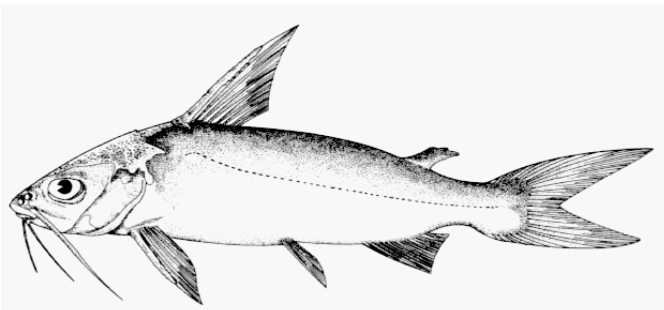
Demersal eggs that produce pelagic larvae

Some species produce nests of small demersal eggs (on the ocean floor) that hatch larvae which float at the surface with tides and currents. Parental care of the nests until the eggs hatch is almost always present. Potential predation on these nests, especially those that are exposed to the open reef is always great.



Clownfish and other damsel fish, dottybacks, grammas, gobies, blennies, and triggerfish are among the reef fish that spawn demersal eggs.

Mouth brooders that produce demersal postlarvae or juveniles



Sea catfish (Ariidae) carry relatively small numbers of fertilised eggs in their mouth until they hatch. They continue to carry the young entirely through early development and the resulting post larvae or juvenile immediately assumes life on the sea floor after leaving the parent. The catfish brood mass contains only 15–170 fertilised eggs.

The male catfish carries the eggs and the number of eggs in the brood mass is dependent on the size of the male: the larger the fish, the larger the mouth and the more eggs that can be carried. Brooding lasts from 4–6 weeks, during which time the male doesn't feed.

Mouth brooding has the advantage, like pelagic spawning fish, of not having to prepare or guard a nest site, and also an advantage similar to the nest makers, of protection during the very vulnerable egg and early embryonic stages.

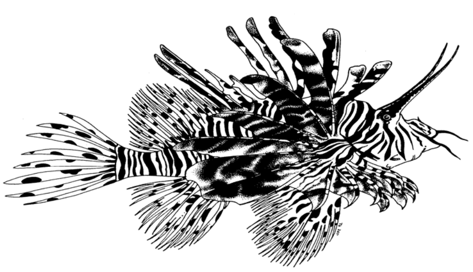
Mouth brooders that produce pelagic larvae

Other mouth brooders produce relatively small eggs that become pelagic larvae. Mouth brooders that carry relatively small eggs that become pelagic larvae have the advantages of a secure brooding method, production of a relatively large number of eggs per spawn, larvae that are well developed at hatching, and a broad distribution of young through dispersal in the plankton.

The male is always the brooding parent in marine mouth brooders. Although the eggs are kept in the oral cavity of the male, they are still exposed to, and oxygenated by, the marine waters that pass through the mouth and gills of the male.

Only the jawfish (Opisotgnathidae) and the cardinalfish (Apogonidae) are small egg, mouth brooding reef fish that produce pelagic larvae.

Pelagic eggs rafted, or attached, and floating



Some species, such as scorpionfish, lionfish, frogfish and angler fish, produce pelagic eggs that are bound to each other in a dense gelatinous medium, and others, such as flying fish, produce eggs that have long tendrils that become snagged on floating weed and debris and keep the egg afloat. The eggs are usually kept together in the raft or nest until hatching and then the larvae become pelagic and are dispersed by the currents.

Pelagic eggs that produce pelagic larvae

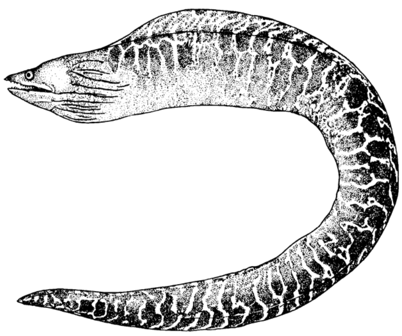
By far the most common reproductive method among tropical marine fish is the production of vast numbers of small, externally fertilized pelagic eggs that hatch small pelagic larvae. There is no parental care of the embryo, larvae or juvenile. Many species spawn on almost a daily basis during the optimum spawning periods of the year so that a vast number of eggs are produced to make up for the lack of parental care.

Large fish produce many eggs per spawn, perhaps over a million for the large groupers, while small fish may produce only 300–500 eggs per spawn.

Although strongly influenced by the production of an average female, the productiveness of a species, is dependent on the number of females producing eggs. A very abundant species of small fish can produce more eggs than a rare species of large fish.

Typically, tropical pelagic eggs hatch 20–24 hours after spawning, and the larvae require about 72 hours to develop eyes, gut, and fins before they begin to feed. The larval stage extends from 21–40 days, depending on the species, temperature, available food, and possibly a suitable environment for juvenile survival. Settlement of the post larvae or juvenile may occur in a shallow nursery area or, on or near the offshore reef environment.

Angelfish, surgeonfish, parrotfish, groupers, moray eels, snappers, grunts, mullets, reef drums, porgies, wrasses, and many other species spawn pelagic eggs.

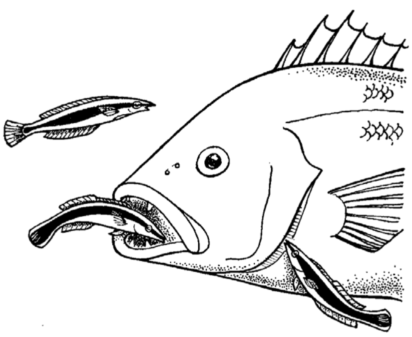


5.4 Spawning behaviour in marine fish

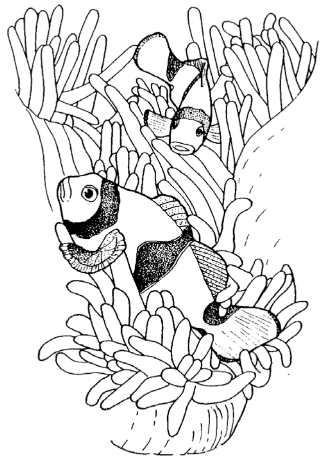
Production of **gametes** (eggs and sperm), is not a simple matter. It would be pointless for individuals of any species to simply shed eggs and sperm and hope that they meet somewhere in the ocean. Even **sessile** species (organisms attached to something that does not move, or has very limited powers of movement) that produce millions of gametes — such as oysters, clams and corals — have elaborate timing (moon phases) and communication (**pheromones**) methods to ensure that the gametes are released at the same time in the same areas, thus ensuring fertilisation of many eggs.

Pheromones *are chemical substances secreted by an animal that convey information and stimulate behavioural responses.*

Mobile species, on the other hand, come together and coordinate the release of sperm and eggs. They must be sure of many things before they can spare the expense of egg and sperm release.



Spawning systems are adapted to all other aspects and behaviour of that particular species. Small species that are adapted to specific sites by feeding behaviour (such as cleaner wrasse), or are very territorial because of a relationship with another species, or are dependent on reef cover for protection from predation, tend to form pairs or small harems.



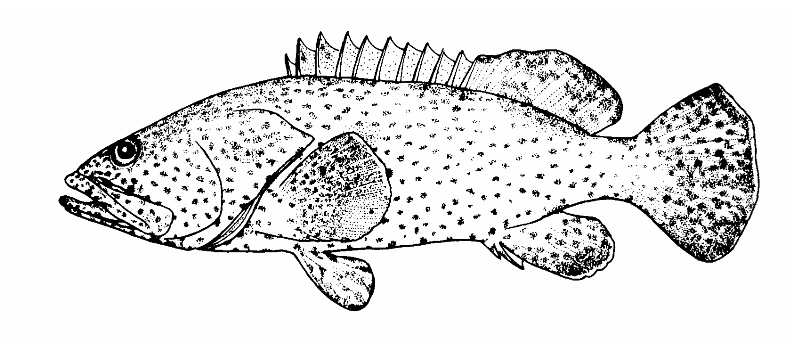
Clownfish, for example, are territorial because of their relationship with a particular sea anemone. This means they live in a defined area and their spawning behaviour reflects this. Clownfish establish **pairs** that stay together for many years. Some species of gobies, blennies, hawkfish, and rabbitfish also form stable pairs.

Some species of fish form spawning **harems**: a single male spawns repeatedly with several females, perhaps up to dozen, and the entire harem occupies the same general area of the reef. The male protects his territory and its resident females from other males that may be passing through or that occupy adjacent territories. Angelfish in the genus *Holocanthus* commonly form spawning harems, one male is dominant and controls an area of several hundred square feet of reef structure, with three to six smaller females in residence. Some species that lay demersal eggs, such as triggerfish and puffer fish, form harems as do some pelagic egg producers such as angelfish, wrasses, and parrotfish.

Other species form pairs only for the immediate spawning and different pairs may form each day or even at different times on the same day. This is known as **promiscuous** (many partners) spawning. Many damselfish spawn in this manner with the male establishing a territory, courting many females, and spawning in turn with each female on the same nest site. The male defends his nest site but does not maintain an established harem of specific females. The females may spawn with several males at various nest sites over the spawning season.

Some species of fish — such wrasses, groupers, tangs, snappers, and jacks — tend to spawn from schools or in spawning aggregations.

Spawning aggregations



This type of spawning behaviour is a type of promiscuity. The selection of spawning partners is random and is based on presence within a spawning aggregation rather than individual selection. It is unique, however, in that the fish migrate to a particular site at a specific time just for the purpose of spawning.

Once at the site, a place and time that favours the distribution and survival of the spawn, intensive spawning occurs over a relatively brief period, and the fish within the spawning aggregation then disperse, often back to reef sites they previously occupied before spawning time. The defining characteristics of this category are migration to the spawning site and the rapid and intense spawning activity. Some species of grouper travel to prominent reef sites year after year and engage in this type of spawning behaviour.

These species form schools only when it comes time to mate. Spawning aggregations typically form during specific seasons, moon phases and times of the day. The fish will form a large school and release their eggs and sperm in massive quantities.

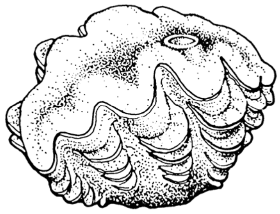
As many as 10,000 fish gather during some aggregations, and often several different species aggregate simultaneously at the same site. Releasing a massive onslaught of fertilised eggs in the water may have advantages over a solitary egg, because a massive onslaught may be enough to overwhelm the egg predators. The predators will eat as many as they can, but some eggs will inevitably survive.

Many aggregating fish species reproduce only at spawning aggregation sites.

Spawning aggregations also help ensure individuals of a species have more chance of finding another individual to mate with; instinctively they know that many other individuals of their own species will be gathered in a particular spot at a certain time, so they don't have to rely on finding them by chance in the vast ocean.

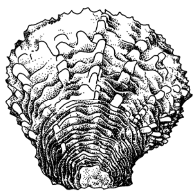
5.5 Invertebrate biology and reproduction

Feeding methods and food sources for invertebrates are as varied as the many different invertebrates themselves. Some invertebrates are carnivorous. For example, jellyfish and squid often feed on fish. Other invertebrates, such as chitons and sea urchins, graze on algae or seaweed. Some shellfish and starfish prey on shellfish. Sea snails have a special rasp-like tongue, called a radula, which some species use to graze on algae, and other use to drill holes in the shells of their prey so they can eat the flesh. Some are parasites than live in or on other species, while others are filter feeders that strain tiny plant and animal matter from the water. Clams and other two-shelled molluscs for example, feed by pumping large quantities of seawater through their systems each day, straining out small food particles in the process.

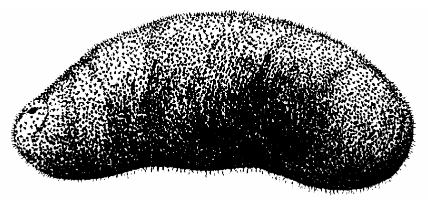


Invertebrates also have many different reproductive strategies. Squid and octopus use a special tentacle to deliver a sperm packet inside the female. The female later lays a number of eggs out of which small larvae hatch. The female octopus often dies after its eggs have hatched because it stays and makes sure that the eggs stay clean and aerated, and during this time it does not eat any food and so eventually starves to death.

Many crustaceans also use specialised appendages to pass sperm from the male to the female, or to hold the female in place. After hatching, the crustacean goes through a number of larval stages before settling and becoming an adult.



Most sea snails have separate sexes. The males deposit sperm in females and the fertilized eggs are released in gelatinous strings, cases or capsules. Two-shelled molluscs generally use external fertilisation, with separate sexes releasing sperm and eggs into the sea. After fertilisation the eggs hatch into small larval stages and may drift for a week or so before settling and growing into the adult form.



Sea cucumbers also have separate sexes and use external fertilisation. When spawning, sea cucumbers adopt a “cobra-like” position with the front end elevated off the seafloor bottom. Most sea cucumbers spawn during the warmer months.

The average lifespan of a sea cucumber is 5–10 years and most species first reproduce at 2–6 years of age. Fertilised eggs develop into pelagic larvae that may spend 50–90 days in the plankton, being widely dispersed by water currents. As with other invertebrates that do not move far or do not move at all, sea cucumbers that broadcast sperm or eggs into the water column must be at a certain density to ensure fertilisation success; in other words, there must be enough breeding adults in the same area to ensure that sperm and eggs meet and that fertilisation occurs.

Some invertebrates reproduce asexually. Asexual reproduction results in a genetically identical copy of the parent and is characteristic of cnidarians such as corals and hydroids, and certain worms and sea squirts. Asexual reproduction involves the parent dividing or budding to produce copies of itself without the input of another adult. Some sea cucumbers are also able to divide in two.

Because many invertebrates are not able to move very far or fast, there needs to be a number of mature individuals of both sexes close together in order for reproduction to be successful. If the individuals are too far apart then eggs and sperm are unlikely to meet and there will be no fertilisation. Reduction of population densities by fishing may render remaining individuals incapable of successful reproduction, due to the greater distance between males and females. Invertebrates can especially benefit from protected areas, or selective harvesting that leaves groups of mature individuals behind.

6 LIFE CYCLES

6.1 Introduction

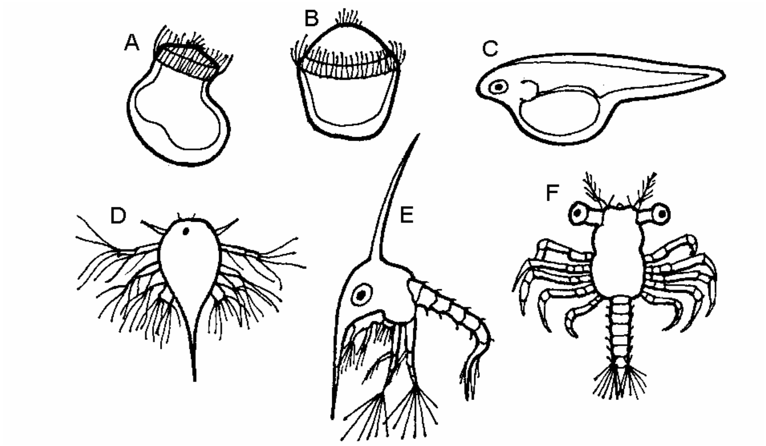
Mammals, birds and reptiles have quite simple life cycles, as do some invertebrate animals. In simple life cycles, the embryo develops directly into a form that resembles the adult.

Many other animals have complex life cycles. Complex life cycles contain stages that do not resemble the juvenile/adult form, and which experience very different conditions. Life stages that have hatched from the egg but do not resemble the juvenile or adult are called **larval stages**. Tadpoles are larvae of frogs and toads, and caterpillars are larvae of butterflies and moths. Larvae undergo significant changes (sudden or gradual) before they reach the juvenile/adult form. The larval stage differs from the adult stage in that it inhabits a different environment, or consumes different types of food than the adult.

The functions of the larval stage are quite varied, but usually include continued development and changes, and growth. The difference between a larval development and embryonic development (where the embryo develops inside the mother or inside an egg) is that the larva fends for itself while the development continues. It is not provided for by its parents (or, it has used up these provisions), so it obtains food on its own.

6.2 Larval forms

The larval stages of many marine animals drift freely in the ocean (as part of the plankton), feeding on smaller plants and animals, until they reach juvenile size and form and start living in the juvenile/adult habitat. Many larvae have special adaptations for planktonic life, such as spines (for protection and flotation) and **setose** ("hairy") appendages for feeding. In some crustaceans, certain larval stages take place within the egg.



A) sea snail trocophore larva
B) clam veliger larva
C) fish larva
D) shrimp nauplius larva
E) crab zoea
F) crab megalopa

Sizes range from 0.15 mm (trocophore) to > 4mm (fish larva)

Different larval forms of some marine animals.

Particular kinds of larvae may occur in two or more groups of animals that are quite different as adults. The trochophore larva occurs in marine annelid worms (segmented worms related to earthworms) and in many molluscs (clams, chitons, snails, etc.).

Nauplius larvae occur (either free-living or in the egg) in almost all crustaceans, from tiny barnacles and brine shrimp to large crabs and lobsters. Why do you think similar larval stages occur in such different groups of animals?

Advantages of planktonic larvae

Planktonic larvae of marine animals offer ecological advantages.

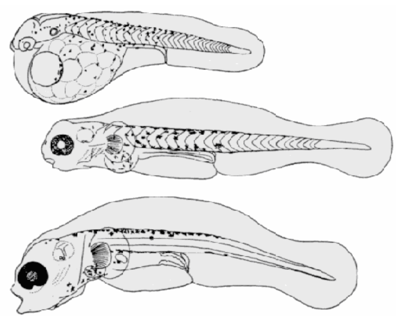
One benefit of planktonic larvae is in the distribution of the species. Planktonic larvae drift from their birth place, and (a) may come upon unoccupied habitats, (b) may avoid competition or inbreeding with siblings, and (c) may reduce the chance of complete reproductive failure in the event of a local catastrophe (especially important from the parents' point of view).

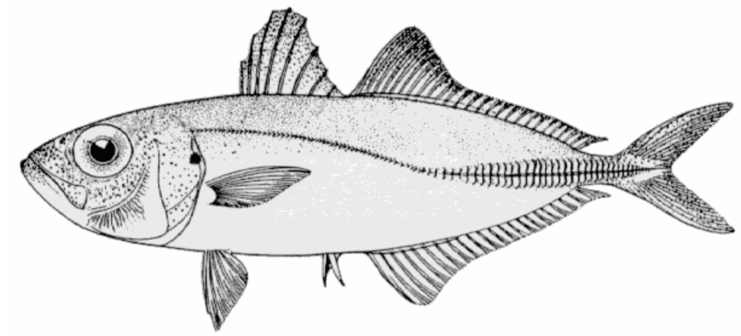
The larval stage is also self-sufficient, so that growth and development can continue in the absence of parental provisioning. In general, then, what is the advantage to a parent in producing tiny planktonic larvae instead of large, better-developed young? What are the disadvantages? How many must be produced, compared to the number of well developed young that can be produced?

6.3 Life cycles of some important harvested species

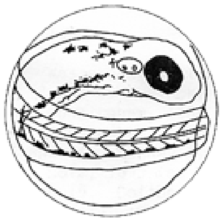
Fish

Nearly all bony fish, especially marine fish, have a pelagic larval stage that is very different from the adult in terms of body shape and characteristics. In general, these larvae live in different places from the adult, have different behaviours, eat different food and have different predators.





Bigeye scad larvae, from 1.7 mm to 2.5 mm **Adult 75 mm**



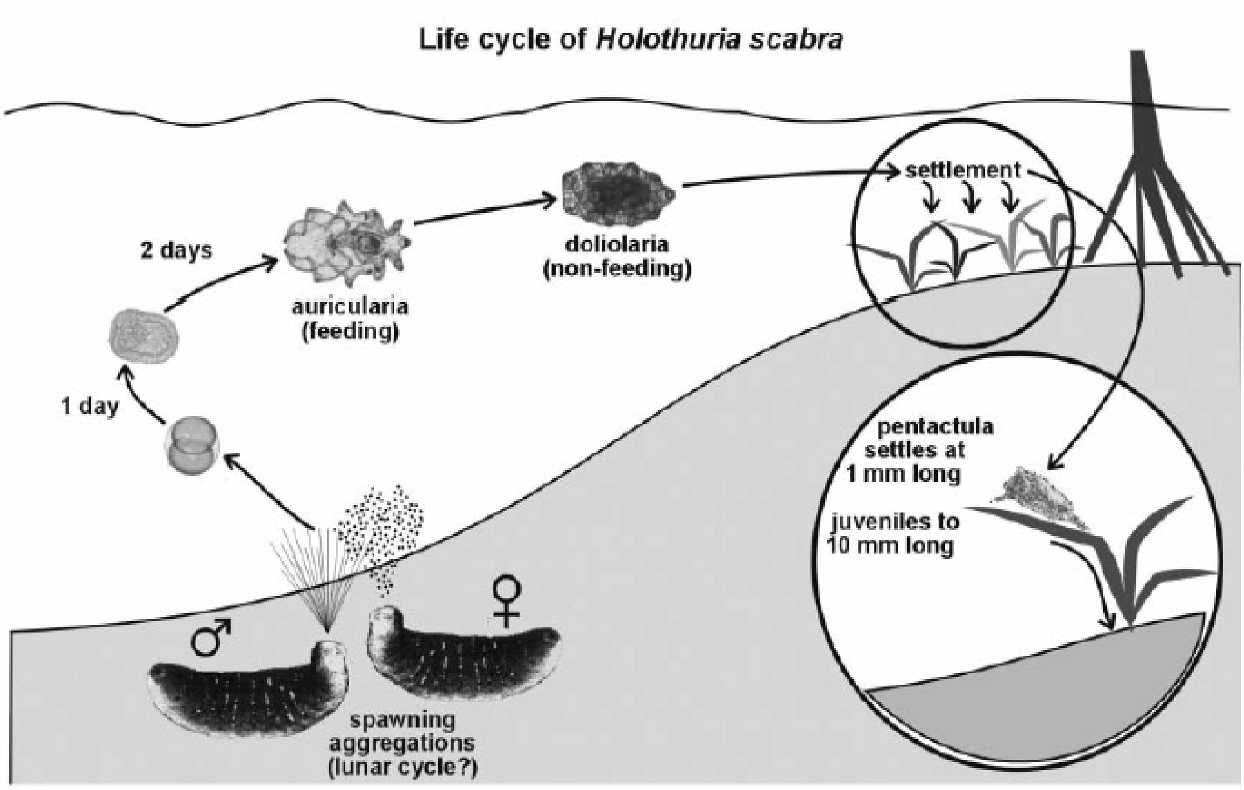
Most fish reproduce simply by releasing eggs and sperm into the water. Once the egg is fertilised the embryo will form inside the hardened egg. The embryo will start to develop organs, and eventually eyespots and the tail can be seen inside the egg. The tail of the embryo then breaks out of the shell and the embryo becomes a free-swimming larva.

Newly hatched larvae have a yolk sac that is a source of nutrition for the larvae. These larvae can survive for two to four days by feeding off their yolk sac food supply, by which stage they are developed enough to feed on live prey. Once the mouth has formed and the eyes are partially developed, the larva is ready to progress to live food.

Metamorphosis, or change to the next stage, is the process that signifies the end of the larval stage. After metamorphosis the fish are considered juveniles and will acquire the characteristics of an adult fish such as coloration and fin. Some fish will take days or months to reach this stage, depending on the species. Juveniles are not considered to be adults until they are sexually mature, or able to reproduce and begin the cycle again. The juveniles of many fish species grow in nursery areas separate from the adult population, including reefs, bays, estuaries and mangroves.

Sea cucumbers

After fertilisation, the egg hatches and develops into an **auricularia** larva within about three days, followed by a **doliolaria** larva. Metamorphosis produces a **pentactula** larva, with the beginnings of adult characteristics. These larval stages last between two and four weeks. Following this, the larva settles to the seabed and becomes a juvenile sea cucumber. For sandfish reared in aquaria, this stage is reached about 13–16 days after spawning. Juveniles are very secretive and hide among seaweed, under stones, and in crevices. They are rarely seen in the adult habitat, possibly because they occupy different habitats or because they are very hard to find.



Juvenile white teatfish have been found attached to algae on seagrass, and sandfish also have been found to settle on seagrass. Recent studies on released juvenile sandfish have shown that mangrove/seagrass areas were the most suitable habitat for settling juveniles, due mainly to low predation rates.

Trochus

Trochus are mainly herbivorous and have separate sexes. Individuals are believed to spawn once or twice each year, most actively in the summer months. Larger adults spawn less frequently, but can produce more than one million eggs. Animals may form spawning aggregates, usually in the evenings around the new moon or full moon phase. Spawning is initiated by males that release sperm into the water column during the incoming tide. This is followed by the release of eggs by nearby females.

About 12 hours after fertilisation, a fully developed **trochophore** larva is formed and is ready to hatch. Within 24 hours after fertilisation, the **veliger** larval stage is reached. Trochus larvae are planktonic, meaning they simply drift with the currents in the water column before they will settle onto a reef.

During the planktonic phase, the larvae rely on egg reserves and do not feed actively. Larvae settle in select places, probably within crevices or holes on reefs with suitable algae and may use chemical cues from resident trochus. Under favourable conditions, the veliger larva settles onto a rocky surface and metamorphoses into a **benthic** (bottom-dwelling) trochus juvenile in three to four days. The settlement phase involves a high loss of larvae because of a failure to settle.

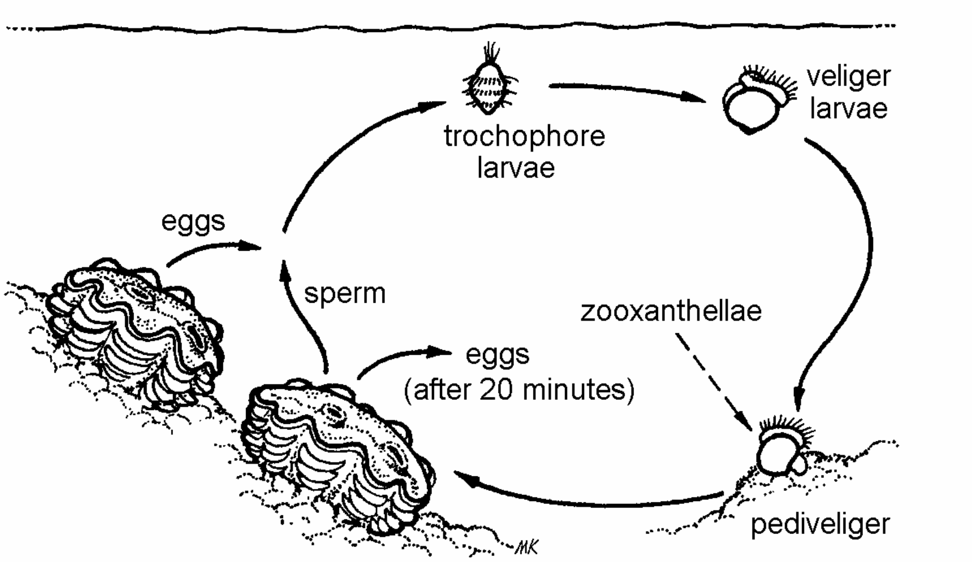
Clams

Giant clams mature first as males in two to three years, and then develop gonads capable of releasing sperm or eggs. Fertilisation takes place in open water and is followed by a planktonic larval stage. After fertilisation, the typical life stages are the **trochophore** larvae, followed by the **veliger** larvae.

These two forms are free swimming, are found in the plankton, and do not look much like the adult clam. The larvae must swim and feed in the water column until they are sufficiently developed to settle on a suitable substrate, usually sand or coral rubble, and begin their adult life as a sessile clam.

The veliger larva develops a foot and becomes a **pediveliger** that alternately swims and rests on the bottom**.**

Different clam species will choose to settle on a particular substrate that suitable to the adult form of the species. For example, the larvae of mangrove clams that live in soft muddy sediment will prefer to settle in muddy areas, while giant clam larvae will need to settle on healthy reef areas.



The life cycle of the giant clam

Octopus

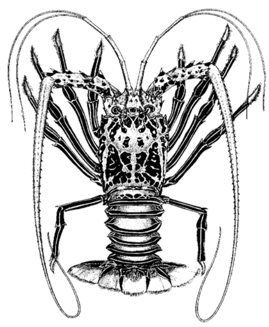
Depending on the species octopus are two or three years old when they mate. The male courts the female and if she is receptive, then he will deposit spermatophores (a “package” of sperm) into the mantle of the female. The female will keep the spermatophores in her mantle cavity until she is ready to fertilise her eggs. The male octopus will die shortly after he deposits his spermatophores into the female.

When the female is ready to lay her eggs she stops feeding and finds a safe place to lay her eggs. The female lays her eggs in strings and it is usually attached to rocks on the roof of her home. Some species will lay thousands of eggs and it may take a week or more to lay all the eggs. After laying the eggs the female stays with the eggs to aerate and protect them. After four to six weeks the eggs hatch. Shortly after the eggs hatch the female octopus will die.

When the young octopuses hatch they spend a portion of their time as plankton in the ocean. The amount of time they spend as plankton depends on the ocean temperatures and the type of octopus. When the young planktonic octopus finds a suitable place it will settle and feed on small prawns and crabs.

Lobster

Adult tropical lobsters migrate from coastal areas to more ocean areas when they are ready to spawn. After fertilisation their larvae undergo more than 11 different body forms in the first six months! During these stages the larvae are know as **phyllosoma** and float with the ocean currents. After this it progress to a swimming larval form called **puerulus**, which may actively seek out suitable sea bottom for settlement. The puerulus must find its way to inshore areas before settling. The spawning season is during the warmer months. In the cooler months the puerulus settles into holes or crevices covered with seagrass or algae. Following settlement the juveniles grow to maturity before heading to sea and starting the reproductive cycle all over again.



The great migration — a lobster’s journey

Each spring, thousands of ornate rock lobsters (*Panulirus ornatus*) abandon their home territory in the Torres Strait and travel up to 500 km to the eastern Gulf of Papua.

Walking close to six kilometres every day for up to two months, the young adults brave predators and fishers to reach their breeding grounds, such as those around Yule Island. Here, between November and March, they will mate and release their larvae into the Hiri Current of the Coral Sea. After mating, the females lay 300,000–750,000 eggs. These eggs are carried under her abdomen until they hatch, three to nine weeks later. Billions of **phyllosoma** larvae are then released into the Hiri Current of the Coral Sea, where an uncertain future awaits. The physical stress of the migration and spawning takes its toll on the adults, and about 95% of the lobsters die after breeding in the ensuing summer. But six months later their progeny, the tiny larvae, drift into Torres Strait, where they will remain until they too are ready to spawn.

Larvae remain in the planktonic phyllosoma stage for five to seven months, increasing in size as they moult (shed their shell). At least nine phyllosoma stages are recognisable. In the first stage, the transparent larvae are less than two millimetres long and just visible to the human eye. But by about the ninth stage, they measure some 35 mm. At the last phyllosoma moult, the young crustacean emerges as a **puerulus**, and at last looks something like a lobster.

From plankton sampling and the use of satellite-tracked drifters released from the Gulf of Papua, scientists have found that most phyllosoma and puerulus are carried back to their parents' home ground in Torres Strait, via the South Equatorial Current and the oceanic whirlpool of the Coral Sea Gyre. Some larvae are not so lucky, however, and are swept south by the East Australian Current to unsuitable habitats.

On reaching the inshore nursery of Torres Strait, the puereli settle into holes or crevices in rocks or reefs sheltered by macroalgae and/or seagrass. The number of moults these pueruli make is unknown, but by the end of their first year on the seabed they have become juvenile rock lobsters.

Moulting occurs throughout the life of the lobster and the process takes several days. In the spring of their third year, the call to mate drives the young rock lobsters to repeat the 500-km migration their parents made to the breeding grounds around the eastern Gulf of Papua.

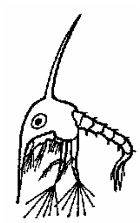
Currents in the region assist the lobster larvae in their journey.

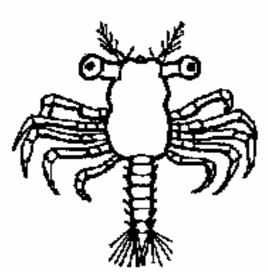
Scientists have been recording a decline in lobster numbers for some years. The main reason for the decline is that too many spawning adults are being caught by fishermen, and are therefore not repopulating the fishery. In addition, habitat change has not helped the lobster. Floods in 1992 and 1999 in Papua New Guinea flushed silt-laden freshwater into the lobster habitat, killing vast areas of seagrass. Healthy seagrass areas are essential to the lobster life cycle as they support many of the creatures that lobsters feed on, and prevent sand erosion from covering lobster habitat.

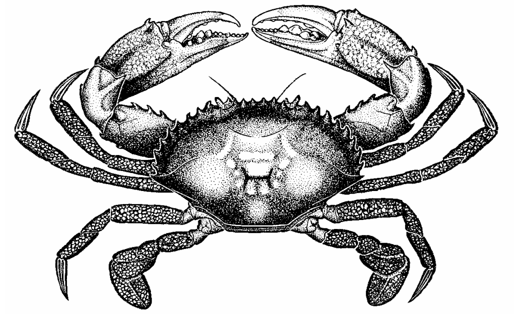
Several management strategies are being suggested to help the ornate rock lobster recover from overfishing and the loss of seagrass habitat. These are discussed in the section on fisheries management.

Crabs

Most crabs mate after the female has moulted and while her shell is still soft. After mating, the fertilised eggs are carried by the mother outside her body, under a flap called her abdomen, or telson. These eggs are actually outside the mother, the flap does not completely enclose them. When the eggs hatch, they are released as a type of larvae called a **zoea**. Zoea float near the surface of the water and feed on small particles. After several zoea stages (separated by moulting periods), they metamorphose into **megalops** larvae. Megalops look more like an adult crab and are bigger than the zoea. Finally, the megalops metamorphoses into an adult crab.



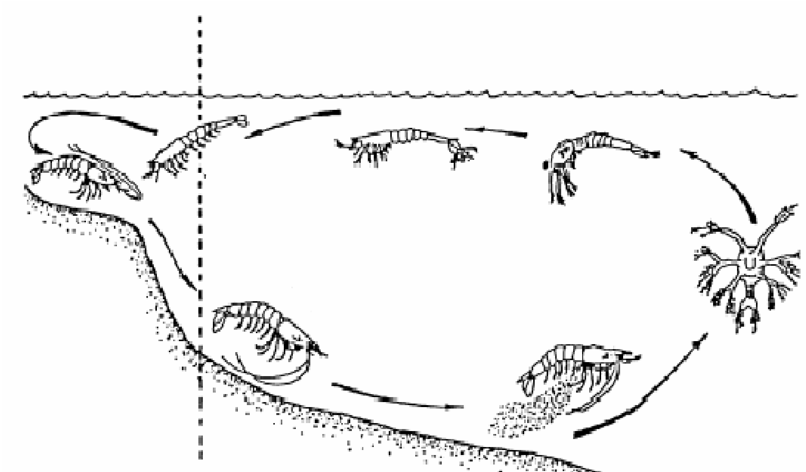




Zoea **Megalops** **Adult**

Prawns

Prawns spawn in deeper water and have several planktonic stages before the larvae reach inshore nursery areas such as mangroves where they live and grow to be juveniles. A single female produces between 500,000 and 1,000,000 eggs and may spawn several times.



During mating the male transfers a packet of sperm, called **spermatophore**, to the female. Like most crabs, some prawns mate when the female's exoskeleton is still soft immediately after moulting. The spermatophore is glued to the underside of the females and spawning occurs almost immediately. Eggs are fertilized as they are ejected past the spermatophore. They then sink to the ocean floor and after about 12–24 hours hatch into minute larvae which move into the water column.

Natural mortality rates are extremely high for larval and juvenile prawns. Probably less than one or two percent of the eggs spawned will survive to become adults. Postlarval prawns seem to settle out in the shallow waters in the upper ends of salt marshes or mangrove tidal creeks. Prawns remain in this nursery habitat until they are large enough to migrate out to join the adult population.

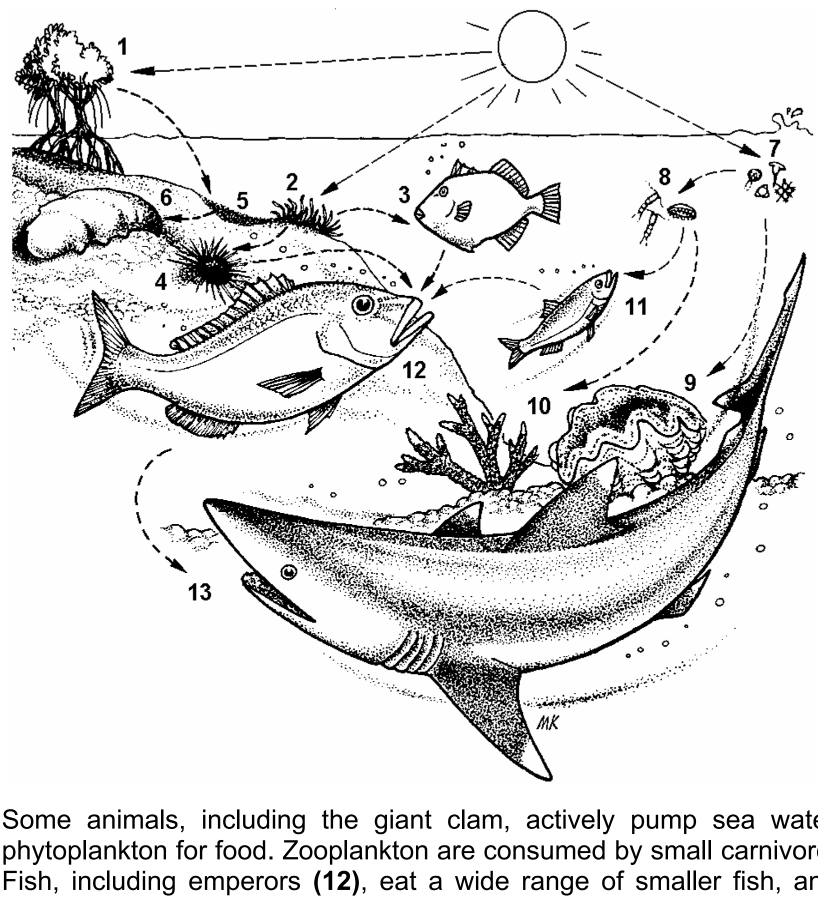
7 FOOD WEBS AND RELATIONSHIPS BETWEEN ECOSYSTEMS

7.1 Overview

Plants and animals interact with their surroundings, such as when they take in nutrients. A community, its surroundings, and interactions form an ecosystem. Although ecosystems were described earlier under separate headings, they are not independent of each other. They are interrelated, and many species migrate between different ecosystems at different stages of their life cycles. Some fish, for example, grow up as juveniles in mangrove areas before migrating out to lagoons as adults. The larvae of other species may drift in the open sea before settling on coral reefs to grow.

Within and between the various ecosystems described in previous sections there is a flow of material and energy. Energy from the sun and dissolved nutrients are used by plants to form tissue through 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 microscopic plants called phytoplankton. These tiny plant cells drift in the sea and are grazed upon by small animals called zooplankton. The plant material is eaten by animals that are in turn eaten by other, usually larger, animals. This complex flow of energy and food material is often referred to as a food web.

This flow of energy and food is shown as a simplified tropical, marine foodweb here.



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 a pool of organic material called detritus **(5)** which is consumed by a wide range of animals, including the sea cucumber **(6)**. Microscopic plants (phytoplankton) – greatly magnified in **(7)** drift near the surface of the sea, and are eaten by small floating animals (zooplankton) – magnified in **(8)**. Some small plant cells (zooxanthellae) live in the tissues of giant clams **(9)** and corals **(10)**.

Some animals, including the giant clam, actively pump sea water through their shells to filter out phytoplankton for food. Zooplankton are consumed by small carnivores such as sardines **(11)** and corals. Fish, including emperors **(12)**, eat a wide range of smaller fish, and are themselves hunted by larger animals such as sharks **(13)**.

ACTIVITY: FIELD TRIP TO A REEF

In this exercise participants will look at marine species they are probably already very familiar with.

They will try and see them now in the light of what has been covered so far in the course, in particular ecosystems; the classification of plants and animals; and biological and reproductive characteristics of marine species).

Materials: Suitable clothes and footwear for a reefwalk. Swimming goggles if wanted. Notebooks for recording observations.

Task: Identify and record as many different species as possible. Local names may be used. Try and classify each species into major groups discussed previously – echinoderms, molluscs, crustaceans, fish or seaweed.

ACTIVITY: RESEARCH PROJECT

Form groups of 3 and choose a marine resource to research (for example, sea cucumber, trochus, prawns, coral, lobster, seaweed). Prepare a talk on the following aspects of the chosen resource:

Biology
Reproduction
Life cycles

Use the information contained in this manual, additional handouts, and the library. Present the project to the class using posters or the whiteboard to explain any details or provide diagrams.

Materials: Butchers paper or large poster paper, coloured textas, tape, whiteboard markers, notepads and pencils.

8 THREATS TO THE MARINE ENVIRONMENT AND FISHERIES

8.1 Loss of key marine environments

So far the course has covered different types of marine environments or ecosystems, food webs, relationships between ecosystems, and the importance of particular ecosystems to the different life stages of many marine animals. The loss or degradation of an important ecosystem can not only directly prevent marine life from living and feeding in a particular area, it can threaten the health of many other species that use that ecosystem for part of their life cycle. We may not even be aware of the number of species that depend on a particular ecosystem, and it can often be quite difficult for people to see that what is done in one area can have an impact in other quite different areas.

Mangroves

Ecological functions of mangroves

Mangrove forests have traditionally been sources of construction wood, herbal medicine, food and dye. The manual has previously covered the importance of mangroves in providing food and shelter for many marine animals, and the role they play in preventing coastal erosion.

Animal and plant habitat	Nursery area for young animals
Food source	Feeding ground
Spawning ground	Shade
Erosion control	Wind, wave, tidal protection
Salt spray protection	Flood and runoff control
Nutrient cycling	Soil improvement
Water purification	Solid waste removal
Weed and disease control	

Mangroves provide habitat for marine and land organisms. They are breeding grounds and nurseries for many marine animals, including rabbitfish, prawns, crabs and lobsters. They protect coastal areas from erosion, maintain and build soil, and protect against cyclones. They are adapted to withstand continuous wave action, periodic drying due to tidal changes, and the influence of saltwater and salt spray. By assisting in the settlement of sediments and filtering water, mangrove forests protect reefs from sedimentation and pollution.

Economic and cultural uses of mangroves

Mangrove forests are often cut or destroyed in order to provide settlements, agricultural land, infrastructure or dumps. Despite the traditional uses of mangrove forests in the Pacific, mangroves are often not highly valued and remain a threatened resource.

Fuel for cooking or heating	House construction
Timber and caulking for boats	Roof thatching
Charcoal production	Weapons and tools
Handicrafts	Fibre and fabric
Fishing equipment	Corks and floats
Mats	Baskets
Rope and twine	Glue
Dyes	Tannin for leather tanning
Medicine	Ornamental plants
Musical instruments	Source of food
Honey production	Food for domestic animals
Animal cages or pens	Recreation or ecotourism

Threats to mangroves

Mangrove forests in the Pacific Islands are vulnerable to over use. For example, mangrove forests in urban areas are susceptible to the effects of urbanisation and development activities. Threats to mangroves include: expansion of squatter settlements, overharvesting of mangrove products, and reclamation of land for commercial, industrial and residential use, drainage outlets and estuarine dredging for flood control. Other threats affecting mangrove areas include: increasing numbers of people living along the coast, commercialisation of mangrove products, pollution, and lack of enforcement of regulations protecting mangroves.

Mangroves are destroyed by
• cutting them for firewood, construction materials, dyes, and other uses;
• land reclamation and coastal development; and
• pollution.

This destruction occurs because of
• population pressures;
• economic rewards;
• lack of alternatives; and
• lack of regulations (especially regulations covering subsistence use) and enforcement.

Protecting mangroves

Mangrove forests need to be protected to ensure they continue playing an important role in coastal ecosystems, while still providing many sustainable products and functions for coastal communities.

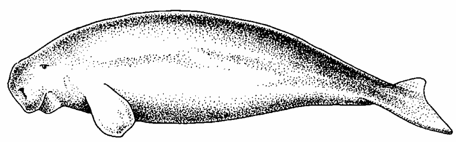
Communities should be aware of the importance and usefulness of mangrove forests, and efforts must be made to ensure that mangroves are protected for the future. In some parts of the Pacific, communities and governments are undertaking measures to ensure the protection and survival of mangrove forests. Occasionally, mangrove management plans have been formulated, but many are yet to be implemented. Governments, NGOs and community groups can be involved in rehabilitative work. Mangrove forests can be replanted and protected to allow these areas to recover from overuse or destruction.

In some countries, certain villages have declared mangroves as part of their marine protected areas. These communities are mindful of the importance of mangrove resources and want to protect them. Communities can replant mangroves to help overcome coastal erosion problems.

Beaches and seagrasses

Beaches are threatened by coastal development, and this can directly impact on shorelines. Indirectly, structures such as wharves and piers can affect current and wave action and lead to the erosion of sand from beaches. Cyclones and storms can cause beach erosion, and the impact of these storms can be increased by inshore deepening resulting from dredging activities and badly placed development in the active beach zone. Sand is often removed from beaches, or dredged from lagoons, to make concrete for the building industry. The mining of sand must be controlled so that there is minimal impact on the coastal environment.

Seagrasses are a group of about 60 species of underwater marine flowering plants. Thousands more associated marine plants and animal species, including sea cucumber, dugong and many fish species, utilise seagrass habitat.



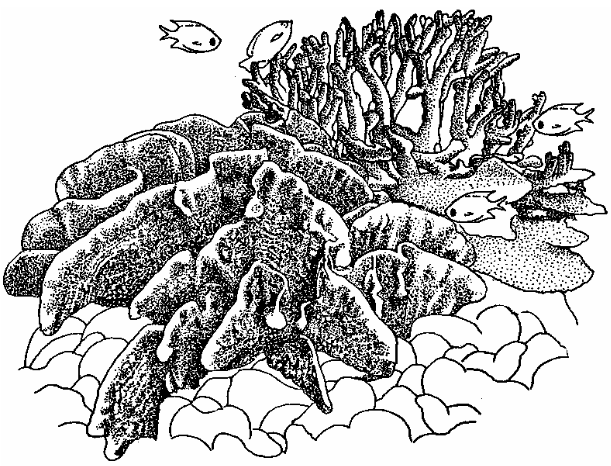
Seagrasses are valuable and overlooked habitats, providing important ecological and economic components of coastal ecosystems worldwide.

Seagrass beds form complex physical structures and are a highly productive ecosystem. This enables them to support considerable numbers and diversity of associated species. Seagrass beds assist in the formation of sand bars, filter coastal waters, reduce the effect of wave action and trap sediments.

Seagrasses are subject to many threats, both human-caused and natural. Natural threats include destruction of seagrass beds by storms and cyclones. Runoff of nutrients and sediments from human activities on land has major impacts in the coastal regions where seagrasses thrive; these indirect human impacts, while difficult to measure, are probably the greatest threat to seagrasses worldwide. Increased amounts sediment and nutrients in the water affect water clarity; seagrasses' relatively high light requirements make them vulnerable to decreases in light penetration of coastal waters. Direct harm to seagrass beds occurs from boating, land reclamation and other construction in the coastal zone, dredge-and-fill activities and destructive fisheries practices. Global climate change may well impact seagrass distribution as sea level rises and severe storms occur more frequently.

General awareness of the importance of seagrass habitat is low compared with higher profile areas such as coral reefs and mangroves. For example, over the last 10 years, the opinion on the status of coral reefs has changed from a predominant view that the majority of coral reefs were unaffected by human activities, to the present view in which the global decline of coral reefs, and the increasing threats to them, are widely acknowledged. A similar understanding of seagrass ecosystems is needed in order to achieve the visibility and recognition necessary to protect this valuable global resource. Public perception translates into political interest. Perceptions of seagrass ecosystems must achieve comparable status with those of coral reef and mangrove ecosystems.

Coral reefs and lagoons



Coral reefs are often called "rainforests of the sea" because of the remarkable diversity of life they support. As one of the most complex ecosystems on Earth, coral reefs are home to over 4,000 different species of fish, 700 species of coral, and thousands of other plants and animals. The health and biodiversity of coral reefs are critical to cultural values and economic livelihoods of millions of people who rely on coral reefs and other coastal environments.

Reefs are the major source of income and food (e.g. fishing and tourism) to coastal communities; they also provide shoreline protection from strong wave action.

Coral reefs are threatened by pollution, sedimentation, coastal construction and development, coral mining, unsustainable harvesting, destructive fishing practices, increasing numbers of predators such as the crown of thorns starfish, careless recreation and use, ocean warming and cyclones.

Since most corals spawn in massive numbers and produce floating gametes, pollutants and toxins can effect coral reproduction and development in a large area. Therefore, much care must be taken to reduce or prevent the spillage and leakage of contaminants into the water, as well as to improve cleanup procedures after such accidents.

Coral reefs can also be damaged by commercial and private vessels. Fuels that leak into the water and the oil that spills into the sea by large tankers are extremely damaging to local corals. The anti-fouling bottom paints used by many boats contribute to the formation of toxic concentrations of tributyl tin (TBT) and several other chemical compounds that may be harmful to corals or other coral species.

Decreases in the amounts of light reaching reefs — such as through direct sedimentation, or from algal blooms caused by high nutrient levels — can kill corals. In addition, increases in the amounts of nutrients enhance the growth of other reef organisms, such as sponges, which may compete with corals for space on crowded reefs.

As our human population increases, so does the harvesting of resources from the sea. Due to overfishing, reef fish populations have been greatly reduced in some areas of the world. The removal of large numbers of reef fish has caused coral reef ecosystems to become unbalanced and has allowed more competitive organisms — such as algae, which were once controlled by large fish populations — to become dominant on reefs in many regions.

Destructive fishing practices such as explosives and poisons are extremely damaging to coral reefs. Blast fishing kills fish indiscriminately and pulverizes living coral. Repeated blasting creates vast deserts of loose coral rubble largely devoid of marine life. Recent studies indicate that it can take more than a century for a reef to recover by natural means once the live coral cover has been destroyed.

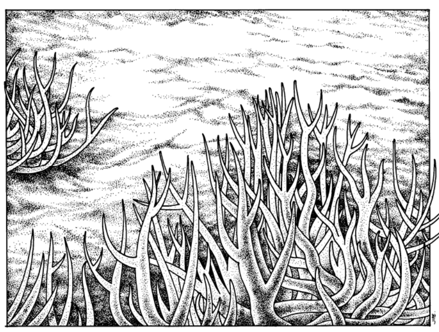
Destructive fishing is covered in more detail later in the manual.

Occasionally, reef predator populations explode. The crown-of- thorns starfish is one predator that can do a lot of damage to a coral reef if its numbers increase significantly. The crown-of-thorns kills corals by feeding on the coral polyps.

The increase in predator numbers may be linked to a decrease in some other species that normally keeps the predators in check. For example, some emperors (*Lethrinus*) species are thought to eat crown-of-thorns; therefore, overharvesting of emperor fish may lead to a population explosion of crown-of-thorns. Certain shellfish are also thought to feed on crown-of-thorns, and so overharvesting these shells could also lead to an increase in the starfish.

Careless recreation or reef use —including boats, inexperienced divers that accidentally kick corals or stir up sediments, reef walking, overturning or breaking corals — can also lead to long-term damage to reefs -. Boat anchors are also very damaging to reefs by breaking and destroying entire colonies. The grounding of large sea-going vessels also results in large sections of coral reefs being destroyed.

Cyclones, severe storms, global warming, climate change and sea level rise also damage coral reefs. Cyclones and storms can physically damage reefs by tearing off corals and killing the more fragile inhabitants; or by depositing large amounts of freshwater through flooding and rivers. After the storm, these slow growing corals might easily be overgrown by quicker growing algae. In addition, these storms generally bring heavy rain which increases runoff and sedimentation. Unusually high sea temperatures can kill reefs by causing coral bleaching.



As has been outlined during the course, corals are made up of small animals called polyps, with small plant cells (zooxanthellae) living in their tissue. These plant cells produce food that is shared with the coral. When the environment is disturbed (for example, by water pollution, rising sea temperatures, or considerable changes in salinity), the algae are lost and the coral changes colour. If the disturbance or stress lasts too long, the coral dies, leaving behind only its white skeleton. This is referred to as coral bleaching.

8.2 Marine pollution

"Pollution" means anything that makes the environment unclean, and especially includes harmful or poisonous substances, or substances that are not biodegradable. Marine animals and plants need clean seawater to live, and are very vulnerable to the effects of pollution caused by dumping rubbish, sewage, fertilisers, oil, detergents, pesticides and even sediments from land clearing.

For thousands of years humans have viewed oceans as vast dumps for disposing of domestic, municipal, and industrial garbage, including tons of sediments dredged from harbours and waterways, sewage sludge, toxic industrial by-products, even low-level radioactive waste. These materials may never become evenly diluted into a weakened mixture, and ocean processes may even concentrate some materials.

Many coastal areas around the world — especially in nations with heavy industry and large populations — are polluted. The Pacific Islands contain some of the least polluted waters in the world, although lagoons near towns are becoming more polluted every year. Marine pollution in the Pacific is increasing as more and more people demand living space, create more sewage, and dump more rubbish. Increasing numbers of people mean more cars, shops, factories and more pollution.

Beach litter and marine debris

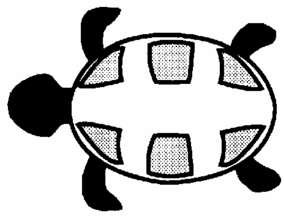
Many large towns in the Pacific Islands have a problem disposing of waste. As a result, streets and coastal areas are littered with rubbish. Even where rubbish bins are provided, some people do not use them. Beer and soda cans and bottles are a particular problem because of the large quantities that are tossed out, and the long-lasting materials the containers are made from (glass and plastic especially). In most Pacific Island towns, people use mangrove swamps or low-lying areas as rubbish dumps. Rotting food and chemicals washed from the dump may create health problems.

People should be careful of eating seafood caught from these areas. In the past, all rubbish was **biodegradable** and there were few poisonous substances dumped into the environment. There was no concern about dropping a coconut frond plate in the water or throwing away a coconut shell after drinking. However, with modern packaging and non-biodegradable containers, the management of waste is an increasing issue.

Many people still see nothing wrong with dumping their rubbish into the sea or on beaches. The problems are more serious on small islands and atolls where there are few places to adequately and safely store rubbish. To make matters worse, a considerable amount of rubbish comes from distant places when ships at sea throw their rubbish overboard. Even though this is illegal, ships still continue to dump many types of rubbish into the ocean.

Plastic bottles and containers can float thousands of kilometres across the ocean.

Most beach litter, especially plastic, takes a long time to break down and may be lying around on our beaches and reefs for hundreds of years. If rubbish dumping continues at the same rate, or increases, there may eventually be more rubbish than beach. Not only does this litter stay in the environment for a very long time, it can also:



- kill fish, turtles, dugongs, corals and other marine species (e.g. plastics can suffocate and strangle fish that swallow it or get tangled in it, old fishing nets can entangle fish, and corals can be smothered or broken by rubbish);
- spoil the appearance of coastal areas for both tourists and local people;
- block cooling water intakes and damage boat engines; and
- foul propellers and endanger human life by causing breakdowns at sea.

Chemicals and heavy metals

Wastes from industries, mines, towns, and farms or from ships may contain chemicals and heavy metals that poison marine life.

Substances that are very dangerous to marine life include:
- heavy metals such as mercury, lead cadmium and copper. These come from mines, shipyards and batteries;
- poisons from antifouling paints;
- pesticides, insecticides and weed killers from farms and towns;
- oil from ships and towns;
- diesel and petrol; and
- detergents and bleach from washing activities.

Heavy metals can come from mines and discarded batteries. Heavy metals such as copper, zinc, lead and mercury are dangerous pollutants. Lead, sometimes stripped from discarded batteries for use as fishing sinkers, is a serious marine pollutant. Some of these metals are particularly bad because they are cumulative — that means that even small amounts 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.

Biomagnification is when creatures that have accumulated toxins in their bodies are eaten by other creatures higher up on the food chain. Toxic substances that are present in prey species become concentrated in predator species.

Shipyards often have poisonous runoff from toxic paints and solvents. Chemicals used in antifouling paints are harmful to marine organisms. 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 that are 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 many countries but unfortunately not worldwide. Tankers and freighters, particularly those flying under foreign flags of convenience, may still use the dangerous paint.

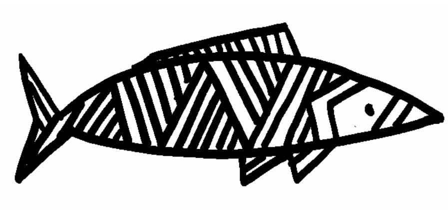
In the Pacific, the use of marine antifouling paint is a serious problem in harbours with a high amount of shipping traffic. Suva Harbour in Fiji has had the unfortunate distinction of having water with the highest recorded concentration of TBT.

Pesticides are poisons used to kill or control pests — organisms that are considered harmful. Those that 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 and remain unchanged in the environment for a long time. Pesticides in water are particularly harmful to the young or larval stages of marine species. Like some heavy metals, certain pesticides can also become concentrated in the flesh of high level carnivorous fish by biomagnification.

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.

Detergents and bleach used for washing clothes or dishes can find their way to the ocean from the kitchen sink and add to problems caused by chemical pollution. Perhaps even more damaging is the direct use of detergents and bleach when clothes are washed directly in the sea, river mouths, or freshwater springs.



Poisons such as bleach are many times more damaging to small animals, such as fish larvae and coral polyps, than they are to large fish. However, because the larvae and polyps are so small, people don’t immediately see the evidence of poisoning, and are often unaware of the effects of their daily washing.

Oil

Oceans absorb far more oil than that from an occasional devastating spill. While major disasters make headlines, hundreds of millions of gallons of oil quietly end up in the seas every year, mostly from non-accidental sources. Shipwrecks can cause large quantities of oil and other contaminants to be released into the sea. Oil is also released when ships and boats pump their bilges, or perform oil and filter changes, often while they are in a harbour. Hoses that leaks when ships are refuelling are also a source of pollution.

Perhaps the most common source of oil as a pollutant is from the disposal of used motor oil. 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 where used oil from motor vehicles can be recycled.

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”.

Down the Drain: 1376 million litres
Used engine oil can end up in waterways. An average oil change uses five quarts; one change can contaminate a million gallons of fresh water. Much of the oil in the runoff from land and municipal and industrial wastes ends up in the oceans.

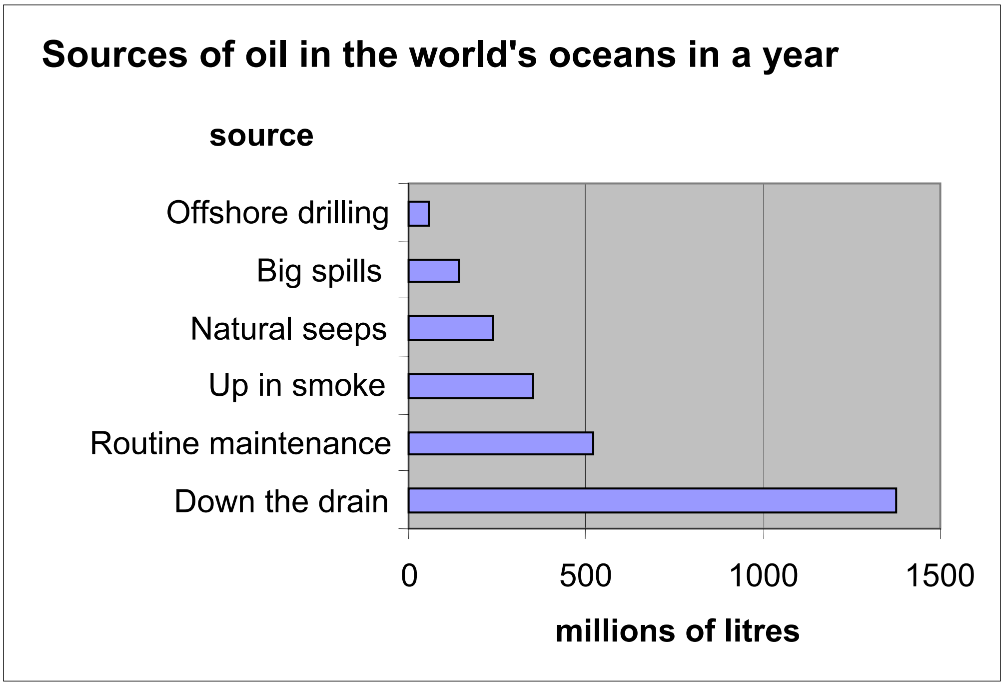
Routine Maintenance: 519 million litres
Every year, bilge cleaning and other ship operations release millions of gallons of oil into navigable waters.

Up in Smoke: 349 million litres
Hundreds of tons of hydrocarbons, which come mainly from cars and industry, are pumped into the air every year. These hydrocarbons eventually settle from the air into the oceans, or end up on the land where they are washed into oceans.

Natural Seeps: 235 million litres
Some ocean oil "pollution" is actually natural. Seepage from the ocean bottom and eroding sedimentary rocks releases oil.

Big Spills: 140 million litres
Only about five percent of oil pollution in oceans is due to major tanker accidents, but one big spill can disrupt sea and shore life for miles.

Offshore Drilling: 57 million litres
Offshore oil production can cause ocean oil pollution from spills and operational discharges.



Sewage

The most common type of pollution in areas with high concentrations of people is caused by sewage — human faeces and urine mixed with water that ends up in the sea. With rapidly growing populations, this will become an increasing problem in Pacific islands.

Sewage can cause massive increases in nutrient levels in the ocean ecosystem. 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.

Other problems associated with sewage include the spread of parasites or bacteria that cause people to become sick. This may require coastal beaches and poisoned shellfish fisheries to be closed. For the most part, cities in the developed world have sewage treatment facilities but many cities in poorer areas have little to no sewage treatment. As the world population continues to increase, sewage pollution will increase with it.

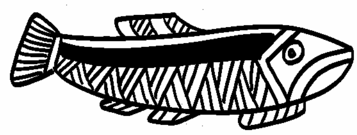
Sewage treatment is expensive and requires large areas of land for the construction of treatment ponds. Most towns in the Pacific Islands rely on septic tanks for sewage disposal. These are underground tanks in which the organic matter in sewage is decomposed through bacterial activity.

High levels of nitrates and phosphates in lagoons and fringing reef areas result in the overgrowth of marine algae such as *Sargassum*, 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 by the increase in 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 areas in the Pacific Islands have high levels of the bacterium.

In Ela Beach in Port Moresby, *E.coli* levels have been sufficiently high to constitute a health hazard and the beach has been declared unsafe for swimming.

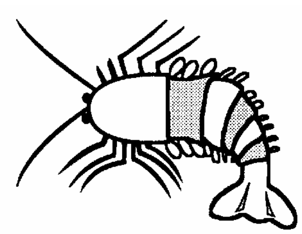
Everything that is poured down drains eventually ends up in the oceans. This includes everything from our homes (toilets, washing machines, bathtubs, dishwashers and so forth), industrial effluents, and even chemicals such as paints and fertilizers that are disposed of down the drain.



8.3 Introduced species

Occasionally fish, invertebrates or sea plants are deliberately introduced into the environment to increase food and generate money and jobs. Sometimes, however, species are introduced by accident. Marine species may be introduced by:

- ships (e.g. organisms in ballast water or on hulls);
- trade in aquarium fish;
- aquaculture; and
- fisheries (e.g. commercial, recreational, stock enhancement, organisms carried on fishing equipment, live bait fish).



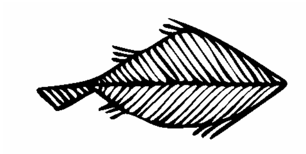
No matter how the species was introduced, the effects on the local ecology are usually irreversible; or at the least, there is a high degree of uncertainty as to the impact. Introductions can change the distribution and abundance of fishery resources through:

- disease;
- changes in predator–prey relationships;
- changes in competition;
- threats to genetic diversity; and
- habitat modification.

Sometimes a fisheries department or business person may try to introduce a new method of fish farming or aquaculture. Animals and plants often escape from the confines of their facilities and this can have serious impacts on local fisheries.

The impacts of an introduced species on a local habitat and its native species can last a long time. Also, the introduced organism is extremely difficult to get rid of once it has taken hold. The balance between the marine environment and native species may never be regained.

It is therefore important that research on the impact of introduced species is done properly before even considering the introduction. The introduced species should also be kept in quarantine so that a qualified person can check for diseases before releasing the species into the environment.



Around the world, thousands of ships, some of them with ballast tanks that hold millions of litres of seawater, routinely pump water *in* at one port, and *out* at another. Ballast water from ships can introduce foreign organisms into the ecosystem when the ballast water is discharged into the harbour.

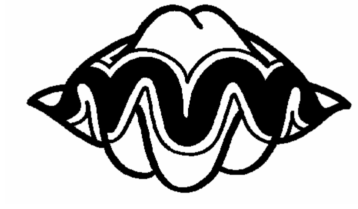
Red tides in New Zealand are thought to be caused by toxic **dinoflagellates** from Japan, that are carried in the ballast water of ore carrier ships. These red tides have killed inshore marine resources and contaminated shellfish, causing many oyster farms to be closed. Even more common than the introduction of marine organisms in ballast water is their transport on the hulls of ships.

8.4 Overfishing and the use of efficient fishing gear

A fishery or fish stock refers to a population of fish of the same type, or species, living in one area. The purpose of fisheries management is to maintain populations of fish over long periods and at the same time continue to harvest a sustainable amount. There is a continuous need to be cautious about how much is harvested, what fishing gear and methods are used, and how the fish stock habitat is maintained.

In some Pacific Islands, inshore fisheries resources — such as giant clams, trochus, sea cucumbers and some popular fish species such as Napoleon wrasse — have been overharvested. These resources have not been fished in a sustainable manner and the rate of harvesting has been greater than the resource's ability to replenish and regenerate.

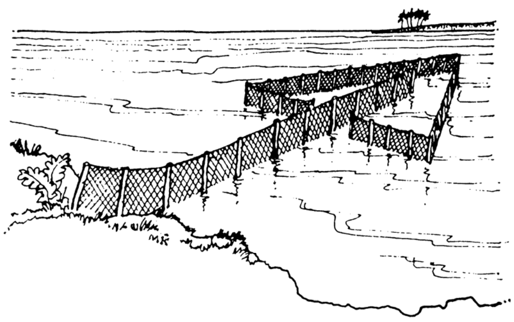
Causes of overfishing include:



- increased subsistence fishing (due to a declining economy and increasing population);
- increased commercialisation (e.g. demand from tourism industry, increase in commercial fishing);

- increased use of destructive and unsustainable fishing practices (e.g. dynamite, small mesh gill nets);
- weakening of traditional management measures; and
- lack of alternative income sources.

Overly efficient fishing gear and increasing numbers of people fishing have made the problem worse. Outboard motors allow people to fish well beyond their traditional fishing areas. Modern materials, such as fine monofilament nylon for gillnets, have made fishing effort more effective. Gillnets made of this material are almost invisible in the water and the thin nylon locks more efficiently behind the gill covers of fish.



Fence traps used in many Pacific Island countries were 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 can result in a dramatic increase in fishing efficiency. One example of this is the availability of underwater torches which enable spearing of large fish resting under corals at night.

Fisheries resources that provide the basis of fisheries development projects can be rapidly depleted. An example in the Pacific is the beche-de-mer fishery. In many areas, the high value species of sea cucumbers have been depleted in a very short time, and commercial fisheries have collapsed. Sea cucumbers populations have been depleted in the past but with the use of hookah diving equipment and the promise of high financial returns, current rates of depletion in some areas are a major cause for concern.

Once catches of the resource start declining and the signs of depletion are evident, management measures must quickly be introduced.

8.5 Overfishing immature fish and broodstock

Overfishing a particular section of a fish stock can have a serious effect on the structure and eventual sustainability of a resource. There is a need to maintain a balance of juveniles and adults to keep a stock healthy in terms of growth and reproduction. The capture of too many immature fish (sometimes referred to as “growth overfishing”), means taking them before they have had a chance to grow to a size that provides the largest yield from the fish stock. Basically, fishing mortality exceeds the fish stock’s gain in weight due to growth.

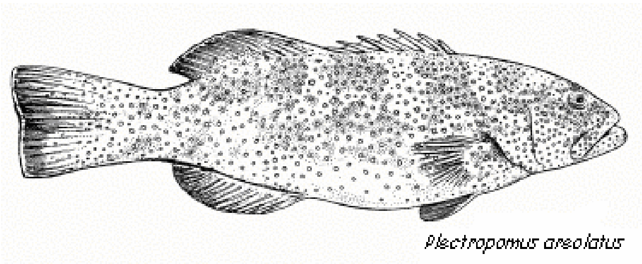
Catching immature fish also removes them from the fish stock before they have had a chance to reproduce and contribute to stock population growth.

With regards to reproduction, egg production in some species is greater in larger fish than in smaller fish and that larger individuals often have greater “breeding power.” Targeting large individuals of these species can greatly reduce the overall reproductive capacity of the species by removing the most efficient and prolific breeders from the population.

Remember that some studies have concluded that one large 12.5 kg grouper would produce the same number of healthy eggs as 212 fish weighing 1.1 kg each (and weighing, in total, 233 kg)!

8.6 Targeting spawning aggregations

In has been previously noted how some species come together at a particular time and place to reproduce in spawning aggregations. Spawning aggregations make the species very vulnerable to fishing pressure at a time when they most need to be protected to ensure that reproduction occurs. Many aggregating fish species reproduce only at aggregation sites, and reproduction at spawning aggregation sites may therefore represent the total reproductive output for that particular fish stock. In other words, if they are heavily fished, then that is the end of that stock.



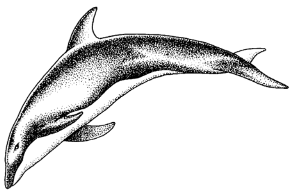
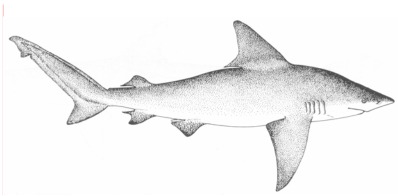
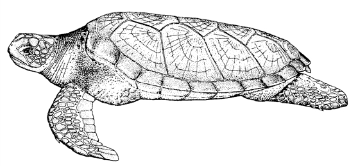
Destructive fishing methods such as dynamite and poisons can also have a huge impact on spawning aggregations by destroying the habitat they use as spawning sites.

8.7 Bycatch

Bycatch refers to the incidental or unintended catch when fishing for other species. Some types of fishing gear are likely to result in a larger bycatch than other types of gear. For example, trawling is not as selective as line fishing or hand collection and the trawler can end up with many more species than the ones targeted. Sometimes the bycatch can be used, either for food or sale, but often it is thrown out. Bycatch can include sharks, turtles, fish, seabirds and marine mammals.

Problems with high levels of bycatch in a fishery include:

- Wastage through discards because the wrong species or the wrong size is caught, inferior quality, low value (no storage on board), unmarketable or surplus to the fishing operations quota.
- Removal of immature fish of commercially valuable species.
- Removal of species that are an important food source for commercially valuable species or other marine wildlife.
- Unknown effects on delicate food webs and balances between species.
- Capture and death of highly regarded or endangered species such as marine mammals, seabirds, sharks and turtles.

8.8 Destructive fishing practices

What are destructive fishing practices?

Destructive fishing practices are fishing methods that: 1) kill or smash corals and rocks; 2) kill many animals, not just the ones a fisherman or woman is fishing for; or 3) do other damage to the marine environment. Examples of destructive methods include the deliberate smashing of corals to catch sheltering fish, and fishing using dynamite or poisons (such as bleach, cyanide or even traditional plants). Even walking over delicate corals can be destructive.

Poison fishing is the use of poisons or plant material to kill or stun fish. Sodium cyanide is used to catch live fish for the aquarium or live food fish trade.

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 is poured into pools that are 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.

Corals provide food and homes for many types of sea animals, plants, and fish. Destructive fishing methods do not select a particular fish or animal. They usually kill everything and damage the environment that fish, shellfish and their food depend on to survive and reproduce. In shallow lagoon and coral reef areas, the damage can be severe and the area can take many years to recover. Explosives and severe poisons such as bleach are many times more damaging to small animals, such as fish larvae and coral polyps, than they are to large fish.
Destroyed coral reefs result in low fish populations that may not recover for more than 20 years.

Blast fishing kills reef fish indiscriminately, including many small fish that have little or no food value. Large blasted areas are slow to recover because corals have difficulty establishing on loose or sandy substrate.

Young corals that settle on this type of substrate are easily killed by algae or sand scour, slowing reef recovery processes. In the absence of suitable habitat, reef fish quickly abandon a demolished reef with the result that local fisheries collapse. Rates of erosion increase because reefs are no longer replenished by living coral.

Repeated heavy blasting creates vast deserts of coral rubble, resulting in total collapse of the local ecosystem. Recovery times for severely damaged reefs may exceed a 100 years.

Killing a coral reef to catch fish makes as much sense as cutting down a coconut tree to get coconuts.

In many Pacific countries toxic plants are used for catching fish. The poisons are made from the roots of the climbing vine, *Derris elliptica,* and the nut of the coastal tree, *Barringtonia asiatica.* These are ground into a paste and wrapped in small parcels made of leaves and placed around a coral head. Fish are then driven to the shelter of the coral head, and become stunned by the poison.

With the growing number of people in many Pacific islands, particularly in urban areas, fishing with traditional poisons is increasingly becoming damaging and unsustainable.

Fish drives and some collecting activities may involve damage to corals from having many people walking over the reef or as a result of overturning or breaking coral to catch sheltering fish. Walking over delicate corals can have a destructive effect on the marine environment. Many corals are very slow growing and can take years to recover from such damage. Always take care when fishing to avoid breaking corals that provide shelter for fish and shellfish. Replace rocks after you overturn them in your search for seafood. This will ensure the marine organisms on the underside of the rock survive to provide food for other animals, and that the rock will continue to provide a home for the animals you collect.

ACTIVITY: THREATS TO FISHERIES AND THE MARINE ENVIRONMENT IN YOUR COMMUNITY

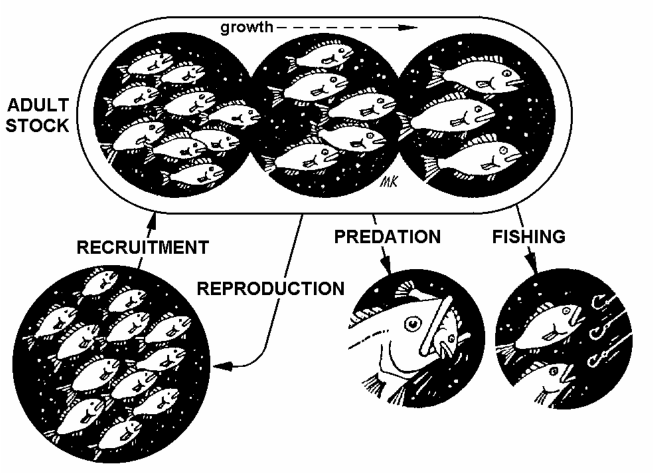
Split up into small groups of four or five for this exercise. Each group is to discuss and take note of local threats and problems relating to fishing and the marine environment in their community. As a group, decide on a method of informing the rest of the class about these problems. Use your imagination: it could be a radio play, a television interview, a song, a cartoon, a poster, a game, a puppet show or any other method your group feels is appropriate to your audience, the class. Try and find a role for everyone in your group.

As a group, present your “problems” to the rest of the class.

9 FUNCTIONS OF FISHERIES MANAGEMENT

9.1 Fish stocks and factors influencing fish stock size

A group of fish of the same type, or species, living in one area is referred to as a fish stock. A fish stock, and the forces acting on it and controlling its numbers, is shown below.



The number of fish increases by the reproduction of adult fish and eventually results in small fish being added, or recruited, into the stock. In addition, the weight, or **biomass**, of the fish stock is increased by the growth of individuals. In the figure to the left, three consecutive age groups, or different year classes, are shown.

At the same time as fish numbers are increasing, the stock is being reduced in numbers and biomass by natural mortality and, in exploited species, by **fishing mortality**. Fishing mortality refers to fish caught by fishers, and natural mortality refers to fish that die by other means, such as being eaten by another animal.

If a fish stock is unexploited or is fished at a low level, losses due to mortality are balanced, on average, by gains through the recruitment of young fish or juveniles. The number of fish in the stock will therefore fluctuate around an average level as long as not too many fish are caught. It is for this reason that fish are referred to as a renewable resource. That is, fish can continue to be caught and used as food forever, as long as the numbers caught are replaced by enough young fish being produced.

However, if levels of exploitation are high, the number of adult fish may be reduced to a level where reproduction is unable to replace the numbers lost. In this case the numbers of fish in the stock will decrease. In severe cases of overfishing, the stock may even disappear altogether (become extinct). In Pacific Islands, many fish stocks have been overfished. Some species of giant clams are now extinct in Micronesia and one species has disappeared from Vanuatu, Fiji and Tonga since the 1970s. Stocks of mullet, which have been caught in large numbers in fence traps, are very low in some islands. Species that have spawning aggregations are particularly vulnerable. The fish congregate in the same area and at the same time, and are therefore easy to catch in large numbers; many species that gather together in spawning aggregations are slow growing and have low **fecundity**. Catching them at spawning time prevents the species from reproducing successfully.

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

9.2 Fisheries management goals

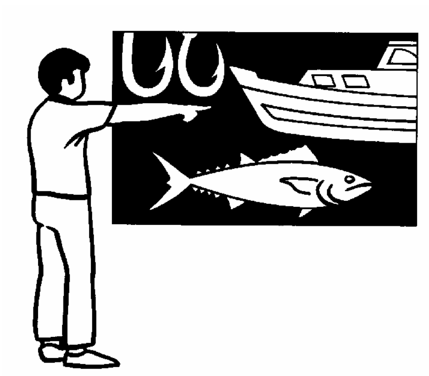
What is fisheries management?

It can be quite hard to define fisheries management. The term is used in a lot of different circumstances. Sometimes people take it in a narrow sense, to mean just regulation, and the enforcement of rules. In other cases people use it in the sense of broad policy-making and the determination of economic or social goals for the fisheries sector.

An intermediate level definition is that fisheries management is the exercise of authority or control in order to achieve pre-determined goals. These might be economic, social or biological goals that have already been decided upon.

Management is the implementation of policy rather than the development of policy. Management usually implies restricting or regulating someone's activities, although this is not universally true. In some cases economic incentives to assist or promote certain sections of the industry might form part of the management policy.

The development of fisheries is closely related to management process, and should go hand-in-hand with it.



Why do we need to manage fisheries?

To achieve or improve:

- economic development
- social benefits
- biological performance
- environmental protection

Fisheries are primarily managed for economic reasons. These might include maximized production, the generation of the maximum amount of money from the resource, earning as much foreign exchange as possible and increasing the economic efficiency of the industry (including reducing the cost of management). Economic goals tend overlap with social goals.

Social goals may include creating as much employment as possible, ensuring that benefits go to certain social groups and to support related industries such as boatbuilding or seafood processing. Ensuring that the benefits go to certain social groups may aim to distribute the benefits widely rather than creating wealth for a small number of people. It may also prioritise subsistence or recreational activities at the expense of commercial activities or it may aim to support poor coastal communities.

Biological goals are primarily in support of economic goals. These goals may include the prevention of overfishing by ensuring enough breeding adults remain to reproduce and maintain the population, and by ensuring enough young are left to grow into breeding adults. The goal may be to achieve the maximum or optimum sustainable yield from the resource. It could also be aimed at restoring a depleted resource or protecting endangered or threatened species.

Environmental goals may be to prevent fishing activities with the potential to cause environmental degradation. This could include fishing methods that cause habitat damage such as trawling or poison fishing, or excessive catching of by-catch or non-target species. Environmental goals may also include controlling pollution such as bilge oil and garbage from ships or pollution from land-based processing activities.

What does “sustainable” mean in relation to fisheries management?

The term “sustainability” is often used in relation to fisheries management. It is almost always stated as an aspect of the management goal. It is helpful to revisit the concept and be clear about what it means.

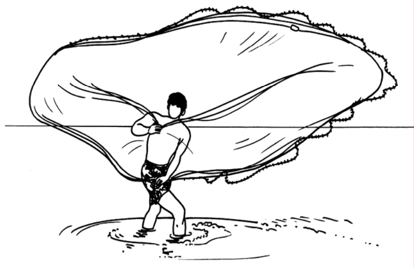
The term **sustainable** means something that is continuous and can be kept going indefinitely. An example of sustainable harvesting is a small number of people fishing for a particular type of fish or collecting a particular animal from the sea year after year after year on an ongoing basis so that their children and their children’s children are still able harvest that particular animal. Sustainable use of a resource allows future generations to benefit from the resource. It means fishing so that there will be similar quantities available each year and there will be stability in the pattern of fishing from year to year with fishers able to plan ahead and invest on the basis that the production will be maintained.

Unsustainable use is taking everything now and leaving nothing for the future. Unsustainable use of a resource is characterised by unstable, frequently changing or inconsistent policies, boom and bust fishing; and no long term benefit from, or investment in, the industry.

An example of extremely unsustainable harvesting is using dynamite to catch fish. This not only catches the fish but very quickly destroys the environment and the food on which the fish depend. The fisherman’s children will not be able to continue with that sort of fishing, or any sort of fishing, because the fishing method is very destructive. Nothing can live after dynamite has been used so the fishing is not continuous or sustainable.

Even less extreme types of fishing can be unsustainable. For example just having too many people taking too many fish or shellfish can be unsustainable. It may just take a little longer for the problem to become obvious. When there are many people fishing they may catch so much of the fish population that there are too few left to reproduce and renew the resource. There will not be enough young fish or invertebrates to replace the numbers lost to fishing and natural causes. In this case the numbers will decrease, the stock will continue to reduce in size and people will find it more and more difficult to find fish to catch.

Sustainable harvesting practices attempt to turn around this pattern of a decreasing fish stock by making sure enough adult fish are left to reproduce, and by ensuring the environment is not damaged by the fishing method. It tries to find the balance mentioned earlier whereby the number of animals being taken from the stock is balanced by the number of young entering.



This is not an easy job, there are many other factors affecting a fish stock that haven’t been mentioned here. These include environmental factors, competition for space and food, and interactions between different species. Not all things affecting the numbers and health of fish stocks are fully understood, but we do know that without management an overexploited fish stock will eventually start to decline.

9.3 Fisheries management measures and what they aim to achieve

The goals of fisheries management and sustainability have been discussed. How are those goals achieved, and what are the practical aspects of fisheries management?

The fisheries regulations described here are used in various Pacific Island countries to reduce the amount of fishing, prevent the capture of small individuals, protect a species during its breeding season, or protect the environment on which it depends. These management tools fall into two broad categories: 1) **input** controls that limit the fishing techniques or effort that is put into a fishery, and 2) **output** controls that limit what is taken out of the fishery.

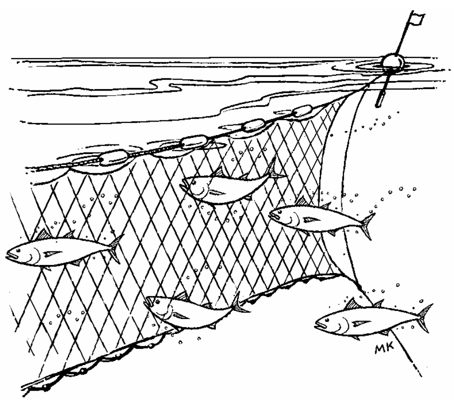
Try and identify which of the following management measures are input controls and which are an output controls.

Limiting the number of fishers

As an alternative to allowing anyone into a fishery, a government may restrict access to holders of a licence. This management measure is the easiest to enforce. In commercial fisheries, the number of fishers can often be controlled in this way. For example, foreign fishing vessels must pay a licence fee to gain access to the fishing zones of Pacific Island countries and there can often be restrictions on the numbers of licences issued. Licensing may also be applied to some inshore fisheries such as trochus or beche-de-mer. A control on the number of export licences issued is another way of restricting access to a marine resource.

One of the problems with only limiting the number of fishers is that effort tends to increase as vessels become more efficient (larger vessels, better technology etc.). In addition to licences, another method such as quotas, also called total allowable catch (or TAC), may be needed in order to control fishing effort.

Limiting the efficiency and types 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 may be banned in lagoons, or the use of scuba diving to catch lobsters may be banned. These regulations are more appropriate in subsistence fisheries (where the resource provides food for a large number of fishers) than in commercial fisheries where efficiency is more important. In some subsistence fisheries, the survival of the resource depends on *in*efficient exploitation!

Gillnets may be banned or limitations placed on where they can be used. For example, in Tuvalu using gillnets within lagoons is banned or strictly controlled.

Closed areas and seasons

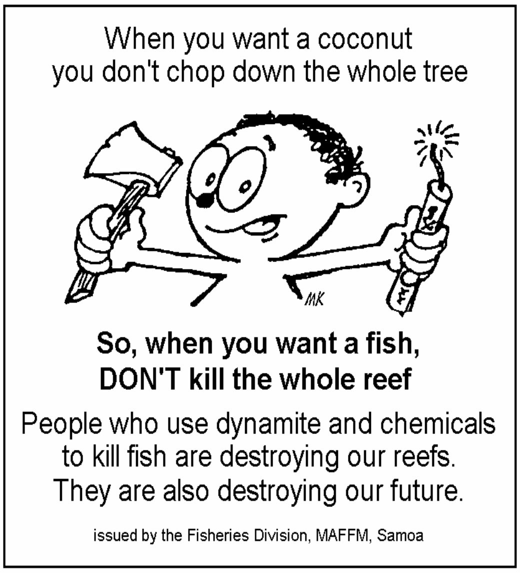
Closed seasons restrict harvesting at a particular time of the year, while closed areas prevent harvesting in particular areas, either temporarily or permanently. Closed seasons and areas are often designed to protect species at vulnerable stages of their life cycle such as spawning adults or migrating juveniles. For example, shallow water mangrove habitats 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 trochus are permanently closed to fishing. Closed seasons can also be used to prevent stocks from being overfished by restricting fishing effort to a short season. In Palau, for example, fishers are allowed to catch trochus during only one month of the year.

A closed area allows at least a small part of the lagoon to recover from damage or overfishing and provides a safe place for fish to live and breed. The larvae of most types of fish and invertebrates drift with the tide and ocean currents and can end up in areas outside the area closed to fishing. Nearby fishing areas will therefore eventually see an increase in catches. It can take some time before a community sees the benefit of a closed area, as fish and invertebrates need time to grow and reach their size at first maturity. It may be several years before catches in areas next to closed areas or reserves improve.

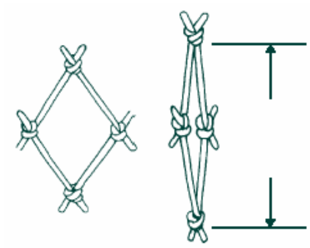
If the spawning season of a particular species is known, a closed season at the time of spawning may allow adults to breed without interference. Turtles, for example, are protected in some countries during the egg-laying months of November to February. Closures can also be used to prevent stocks from being overfished.

Banning destructive fishing methods

Highly destructive fishing methods are illegal in most Pacific Island countries. Even the use of traditional, plant-based poisons such as *Derris* is now banned under national law in most Pacific countries. In the past, the amount of fishing pressure on marine resources was so small that the resource and the environment could cope with a small amount of destructive fishing such as traditional poisons, or methods such as the smashing of corals to catch small, sheltering fish in Samoa.

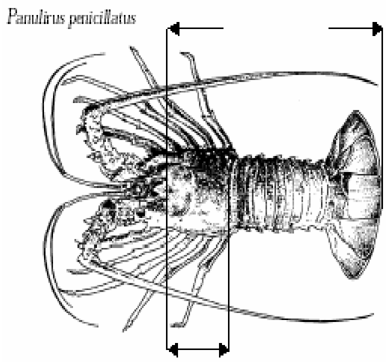


Minimum mesh sizes



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

Size limits (minimum or maximum legal lengths)



In order to limit the size of individuals caught, fish and other animals that are smaller than a prescribed minimum size must be returned to the sea alive. Size limits are intended to allow individual fish to spawn at least once before capture. Minimum legal size limits have been applied by national governments in Pacific Island countries to many species including sea cucumbers, trochus, pearl oysters, giant clams, spiny lobsters, mangrove crabs and many fish species. Size limits are only useful in fisheries where individuals are not harmed by the fishing method, such as molluscs gathered by hand, or crustaceans caught in traps. Some shallow-water fish caught on hooks *may* survive if returned to the water immediately, but this type of regulation has little use for spear-caught and deepwater caught fish species. Fish caught in deep water are unlikely to survive after being hauled to the surface and released.

In order to set mesh size restrictions or minimum size limits for a particular species, scientists must first estimate the size at first maturity for that species.

Maximum size limits place a restriction on the size of larger individuals of a species being caught. This is related to the characteristics discussed in the session on fisheries biology and reproduction whereby larger individuals in a fish stock can be the most important breeders, or broodstock. Limits on the size of species taken will assist in ensuring that the reef ecosystem maintains a balance of juveniles and adults.

Rejecting females or spawning females

Regulations stating that it is illegal to keep females, or females bearing eggs, can only be used sensibly with species in which the sexes can be distinguished easily by fishers, and where the catching method does not harm the individuals caught. The sex of most fish cannot be determined by just looking at them. In most crustaceans, the sexes are readily distinguished, and regulations making it illegal to retain egg-bearing, or "berried", lobsters and crabs are commonly caught in Pacific Islands. This type of regulation may also have application in certain subsistence fisheries. One example is where crabs are caught in traps, and females bearing eggs can be returned to the sea. However, in cases where lobsters are caught by spearing, the regulation is of no use.

TACs and catch quotas

Fisheries agencies may determine that, in order to protect fish stocks, total catches should not exceed a certain TAC. In the Cook Islands trochus fishery, scientists have estimated that fishermen should be allowed to catch about 30% (or about 40 tonnes) of the total trochus stock each year. Once this catch has been reached the fishery is closed. TACs rely on reliable scientific information being collected on what the total allowable catch of a species should be. This often needs to be adjusted each year as conditions change.

Individual quotas may also be set, with a certain quota or catch entitlement being allocated to each fisher or company.

Protecting the marine environment

Protecting the marine environment is essential for ensuring that marine resources have a healthy habitat in which to grow and reproduce. Different government organisations are responsible for drafting laws to protect the marine environment. Such laws can include protecting corals and mangroves, controlling the mining of beach sand, and banning the dumping of rubbish in lagoon waters.

When trying to protect the environment on which an animal depends on, it is necessary to consider where it lives during all stages of its life. If it is a fish that lives in the ocean but spends part of its young life growing in sheltered inshore areas then anything that affects the health of the inshore areas will eventually affect the population of this fish.

The great migration – a lobster's journey continued

The long breeding migration of the ornate rock lobster from the north of Australia to the Gulf of Papua has been discussed already. Lobster numbers have been declining for some years due to fishing pressure and habitat loss. Several management strategies are being suggested to help the ornate rock lobster recover from overfishing and the loss of seagrass habitat.

The size of lobsters that can be legally caught has now increased from a tail length of 100 mm to 115 mm. This minimum size restricts fishing until later in the year and means that catch rates (kg/hour) can be maintained with fewer lobsters. The scientists have also recommended closing the fishery between October and January, which will further protect small lobsters from fishing.

At the same time, scientists and managers are encouraging Torres Strait fishers to move from a tail fishery to a live fishery. Both indigenous fishermen and what are known as "freezer boat" fishermen (generally Europeans), traditionally spear lobsters and remove their heads at sea.

The indigenous fishermen take the tails back to the island in small dinghies, where a processor freezes them for shipping to the United States. The freezer boat fishermen use several small dinghies to bring lobsters to a central boat where the animals are beheaded and the tails frozen on board. This "technology" allows a freezer boat to access more of the fishery and to catch many more lobsters.

By moving to a live fishery, however, the fishers could maintain a similar level of income while catching only half the number of lobsters. This is because live lobsters are worth twice as much as frozen tails. A live lobster might fetch $50 on a live market, while its frozen tail might fetch $25.

For the past five years, there has been a slow move towards a live fishery in Torres Strait. However, the lack of facilities for keeping live lobsters, and the freight costs for flying the product out of the islands have constrained development. At a second ornate rock lobster fishery on the northeast coast of Queensland, more than 95% of the product is sold live.

A third management strategy restricts the number of freezer boat licenses in the fishery. This management measure relates to a 1978 treaty signed between Australia and Papua New Guinea, which ensured the Torres Strait fishery would be managed and preserved for the traditional inhabitants. Under this mandate no limit would be placed on the number of lobsters caught by the islanders. As freezer boats can catch many more lobsters than the indigenous fishermen, license limits will help to reduce the number of lobsters caught and ensure that any future expansion in the fishery is preserved for the islanders.

With all the possible reasons given by scientists for the decline in lobster numbers are the three management measures outlined here sufficient to address all the problems?

10 SUMMARY OF MANAGEMENT MEASURES FOR IMPORTANT MARINE RESOURCES IN PNG

In order to understand the reasons behind fisheries management measures such as National Fisheries Management Plans, it is useful to look at some of the existing regulations for relevant species in PNG. The actual management plans are legal documents and the language used is often difficult for the average person to understand. However, in going to communities to answer questions and provide information on marine resource management and regulations it is essential to have an understanding of what those regulations are. It is also important to be able to give advice on possible resource management measures the community may be able to use, even if these measures are not necessarily recognised in the National legislation or management plans.

10.1 Existing regulations

Beche-de-mer (BDM)

Exporters, traders and storage facility operators need to be **licensed**. To obtain a licence they need to be a PNG citizen or a PNG citizen enterprise. Storage and trade of BDM or BDM products is restricted to licence holders.

Each Province has a **TAC** set every 12 months. The TAC is divided into two groups covering high and low value species. Once the TAC is reached the fishery is closed. If the TAC is exceeded then the excess amount is taken off the next season's TAC. In addition to the **closed season** after the TAC is reached, there is a compulsory closed season each year from October 1 to January 15. Collection, buying and selling of BDM during the closed season is banned.

The use of hookah, scuba gear, underwater lights or surface lights for collecting BDM is prohibited. There is a **size limit** for each species of BDM and the trade in undersized BDM is banned.

Value Group H – High Value Species

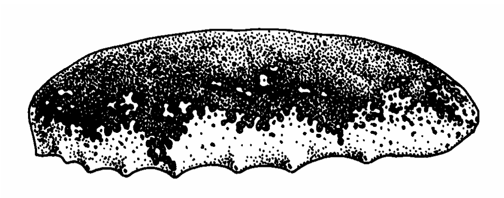
	Trade Name	*Scientific Name*	*Alternative Names*	Live Length (cm)	Dry Length (cm)
1	Sandfish	*Holothuria scabra*	Golden sandfish	22	10
2	Black teatfish	*H. nobilis*	Black mama	22	10
3	White teatfish	*H. fuscogilva*		35	15
4	Greenfish	*Stichopus chloronotus*		20	10
5	Prickly redfish	*Thelenota ananas*		25	15
6	Surf redfish	*Actinopyga mauritiana*	Rough surf	(20)	(8)
7	Blackfish	*A. miliaris*	Big blackfish	15	10
8	Curryfish	*Stichopus hermanni*		25	10
9	Stonefish	*Actinopyga lecanora*		15	10
10	Tigerfish	*Bohadschia argus*	Leopard fish	20	10
11	Brown sandfish	*B. vitiensis*	PK fish	20	10

Value Group L - Low Value Species

	Trade Name	*Scientific Name*	*Alternative name*	Live Length (cm)	Dry Length (cm)
1	Amber fish	*Thelenota anax*	Giant beche-de-mer	20	10
2	Lollyfish	*Holothuria atra*	Biglolly	(30)	(15)
3	Chalk fish	*Bohadschia similis*	False teatfish	(25)	(7)
4	Elephant trunkfish	*Holothuria fuscopuntata*	Trunkfish	(45)	(15)
5	Pink fish	*H. edulis*	Smallbelly	(25)	(10)
6	Snake fish	*H. coluber*			
7	Flower fish	*Pearsonothuria graeffei*	lollyrough, butterfly fish		
8	Deepwater red fish	*Actinopyga echinites*		(25)	(15)

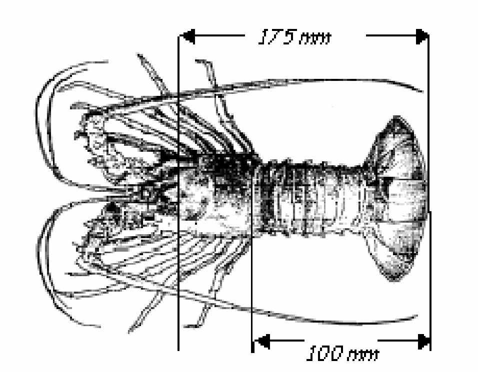
Note: Figures in the brackets are provisional estimates only. NFA endeavors to update this value once new information is made available.

How can the reasons behind the size limits for BDM (or any species) be explained to communities? What about the information considered in relation to the biology and reproduction of particular species? It is very important for communities and people involved in fisheries to understand the reasons behind regulations and fisheries management measures.



Lobster

Exporters and buyers of lobster must be **licensed**.



Different species of lobster have different size limits and it is forbidden to harvest or export any lobster under the minimum size limit.

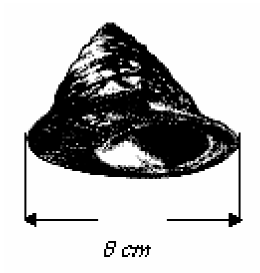
Spiny rock lobster must have a minimum tail length of 100 mm, measured from the bottom of the tail to where it joins the body. Alternatively it can be measured from between the eyes to the end of the tail in which case it must not be less than 175 mm. Spiny rock lobsters are also subject to a minimum **weight regulation.** It is prohibited to harvest or export lobster tail with a weight of less than 169 grams or a total weight of 409 grams.

Slipper lobsters with a carapace length less than 52 mm are not to be harvested or exported. The carapace length is measured from between the eyes to the base of the carapace cover.

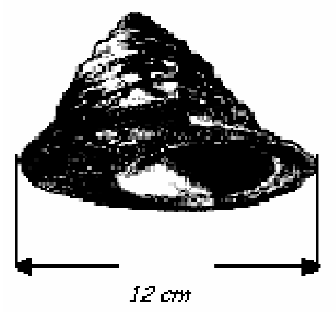
Egg bearing or **berried** female lobsters of any species may not be taken at any time.

In explaining this regulation to fishers and communities it is important to consider the reproduction and biology of lobsters, and other crustaceans. It is important to understand that an egg carrying lobster is potentially going to be responsible for producing hundred of thousands of baby lobster if allowed to carry those eggs until they are hatched. The female lobster carries the already fertilised eggs so it is known that spawning has taken place. It is easy to protect the future stock of lobster by protecting those fertilised eggs.

Trochus



There is a **minimum** and a **maximum size limit** for trochus. It is prohibited to take a trochus that is less than 8 cm or more than 12 cm across its base.



What reasons would you give to fishers or communities as to why there is both a minimum as well as a maximum size limit for trochus?

Other shellfish
Green snail, *Turbo mamoratus*, 15–20 cm (diameter of mouth)
Black lip pearl oyster, *Pinctada margaritifera*, 9 cm minimum (length of base)
Gold lip pearl oyster, *Pinctada maxima*, 13–23 cm (length of base)

Live Reef Food Fish

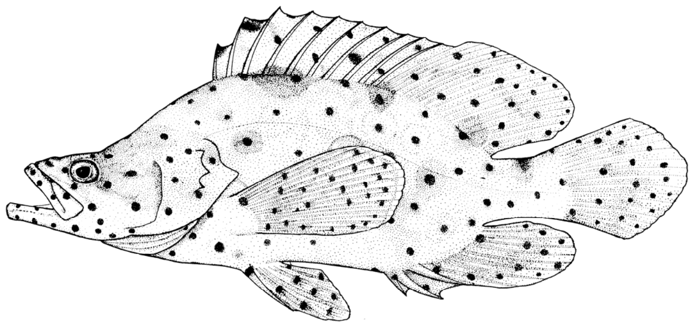
Live reef fish operators must have the following licenses from the National Fisheries Authority (NFA): export, aquaculture, carrier and storage vessels.

A **TAC** for each of the target species may be set for each LRFF management area.

Fishing **methods** and **gear** is restricted to handlining only. Only one permanent fish cage per licensee is allowed for holding fish.

The use of explosives and poisons is banned. Fishing near or on a declared spawning aggregation site is banned. Fishing near or on known diving spots is banned. The use of hookah or scuba for capturing fish for the LRFF trade is banned.

Certain target species have **size limits** and it is prohibited to export fish below the size limit.



Size Limits for Live Reef Food Fish Species

Common name	Scientific name	Lm	Size limit
Coral Cod	*Cephalopholis miniata*		no minimum size
Tomato rockcod	*Cephalopholis sonnerati*		no minimum size
Hump head Maori wrasse	*Chelinus undulatus*	42.03cm	65cm
Black spot tusk fish	*Choerodon schoenlenii*		30cm
Barramundi cod	*Cromileptis altivelis*		40cm
Flowery cod	*Ephinephelus fuscoguttatus*	46.87cm	55cm
Trout cod	*Ephinephelus maculatus*		no minimum size
Camouflage grouper	*Ephinephelus polyphekadion*	33.59cm	37cm
Potato cod	*Ephinephelus tukula*		65cm (>120cm)
Maori grouper (Maori cod)	*Ephinephelus undulostriatus*		45cm
Red throat emperor	*Lethrinus miniatus*		35cm
Managrove jack	*Lutjanus argentimaculatus*	36.1cm	40cm
Red bass	*Lutjanus bohar*		no minimum size
Stripey sea perch	*Lutjanus carponotatus*		25cm
Saddle tailed sea perch	*Lutjanus malabaricus*		40cm
Moses perch	*Lutjanus russelli*		25cm
Red emperor	*Lutjanus sebae*		55cm
Maori Perch	*Lutjanus rivulatus*		55cm
Squaretail coral trout	*Plectropomus areolatus*	33cm	36cm
Chinese footballer trout	*Plectropomus laevis*		60cm
Leopard coral trout	*Plectropomus leopardus*		36cm
Bar cheeked coral trout	*Pletropomus maculates*		36cm
High fin coral trout	*Plectropomus oligocantus*		36cm
Coronation trout	*Variola louti*		no minimum size

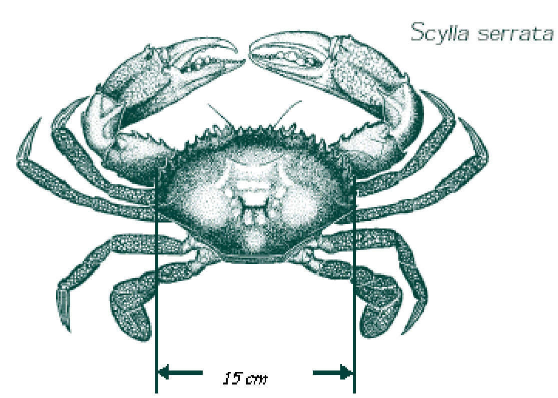
Potato cod has a minimum size limit of 65 cm and a maximum size limit of 120 cm.

The column "Lm" indicates the average length at which the fish first reaches maturity and is able to reproduce.

10.2 Recommendations for other species

Although there are only a few national fisheries management plans in Papua New Guinea at present, it is possible to recommend some simple further regulatory measures for other species, based on regulations in other parts of the Pacific. These could be used as a guide for communities who wish to develop community fisheries management plans.

Mud crabs



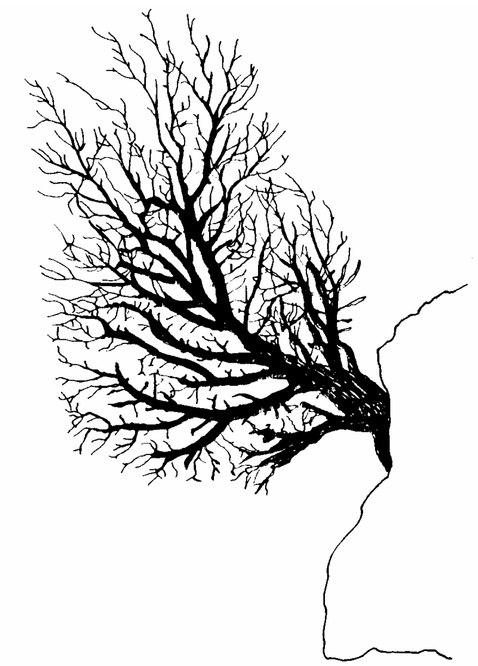
Mud crabs mate when they are between 18 months and two years old, which is when their shell width is between 14 and 15 cm. If there is a restriction on taking mud crabs with a shell width of less than 15 cm the majority of crabs are given a chance to mature and reproduce before they are caught.

General recommendations

The lessons on invertebrate biology and reproduction show that, for invertebrates that don't move far or at all, it is important to leave enough adults behind in one spot so that eggs and sperm can meet for successful reproduction. Marine protected areas can be a useful tool for protecting inshore marine resources by providing undisturbed habitat for fish and invertebrates to live and reproduce.

For all types of crabs and lobster, it can be helpful to have a ban on the collection of egg-carrying, or berried, females. Fisheries management regulations use such a ban because it is easy to recognise a female crab and the contribution of her hundreds of thousands of eggs as potential new recruits to the fishery. Within two to four weeks her eggs will have hatched.

What other recommendations might be considered by communities who wish to protect their marine resources?



ACTIVITY: CURRENT MANAGEMENT MEASURES

This exercise will get the group thinking about some of the forms of fisheries management currently in place in your community. This will build on the information previously collected and presented.

Fisheries management measures and problems

Material: Butchers paper or very large poster paper, charts from the first day, coloured textas, tape, notepads and pencils

Split up into small groups of 4 or 5 again for this exercise. Groups can be different from those used previously. Appoint one person in the group to be a recorder, preferably not the same person who recorded for the last group presentation. Appoint another person to be responsible for giving a presentation on your group's information to the rest of the class at the end of the exercise. Again, make this someone different from the first day's presenters. A lot of this program and the potential village based follow-up work will involve getting used to speaking in front of a group, so it's important that everyone has a go at this role.

Task: Using the charts from the previous exercise, discuss whether there are any controls over the gear or the species on your list. Take notes on whether each management measure is a government or community one. Some examples of these different types of controls are:

National government: a national government law banning the use of certain size mesh on nets.

Provincial, ward or LLG regulation banning fishing in a particular area.

Village or community: a village rule restricting access to a fishing area.

Within the group, discuss how each control relates to the biological characteristics or life cycles of a particular species, or what the control is supposed to achieve in terms of management of that species or gear. Discuss what problems there are with each control.

Using the previously prepared chart tape another piece of paper alongside it with another three columns. Name one column **controls** and fill in beside each species or gear type the controls noted by the group. Note whether the control is a National government, provincial, ward, LLG or village level control. The next column should be **reasons** and note the groups points about controls and how they relate to biological characteristics etc. Finally, the last column should be **problems**, to record any problems noted about each control.

ACTIVITY CONTINUED: CURRENT MANAGEMENT MEASURES

species/fishery	**control**	**reasons**	**problems**
e.g. lobster, national regs	no berried females	protect breeders	not publicized or enforced

Discussion and presentation
A representative from each group is to pin up their finished chart and give a presentation to the rest of the class. Each presentation should include the following:

1. An explanation of each control.

2. An explanation of how you think each control is designed to relate to the biological or reproductive characteristics, or life cycles, of the particular species they are designed to manage.

3. An explanation of each problem relating to the controls.

General discussion: Are the controls realistic? Who do you think should be responsible for setting them and enforcing them? Government? Community? How could some of the problems be addressed?

ACTIVITY: CURRENT MANAGEMENT PLANS

Materials: Copies of existing PNG National Fisheries Management Plans, e.g. Beche de mer, Lobster, LRFF etc.

Task: Read through the management plans and summarise the main management measures and regulations concerning that fishery. Write up your summary in a form that would be useful to use when explaining the regulations to the community.

11 THE IMPORTANCE OF SUBSISTENCE AND SMALL-SCALE FISHING

11.1 Informal employment

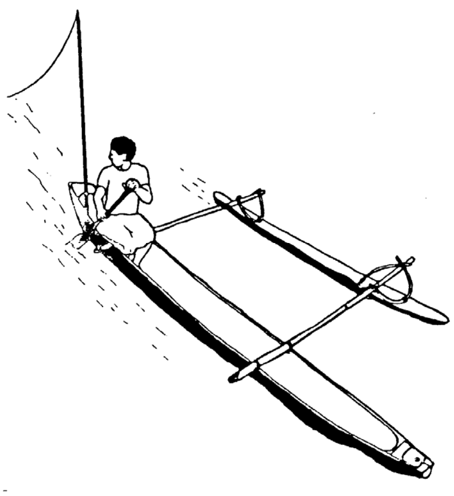
To those involved in commercial fisheries, the importance of the fishing industry to the national economy is obvious and includes:

- exports of fish and fish products earn foreign exchange which helps the country pay for imports;
- the provision of employment for a substantial number of people;
- the catch provides an important source of food for the community; and
- fish, shellfish, seaweed and other aquatic resources collected by families are a crucial part of their livelihood.

While the importance of fisheries may be obvious to those involved in the industry, it is far less obvious to many others. While it is not necessary for everyone to appreciate the significance of any activity in the economy, it can be a problem when that lack of appreciation extends to policymakers, planners, and development agencies. It can mean that the fisheries sector receives a lower priority than it deserves.

One of the keys to ensuring that the fisheries sector receives the level of support it deserves is to make certain that the sectors contribution to the economy is accurately recorded in current economic activity statistics. This means estimating the production of seafood from the subsistence fisheries sector. If goods such as fish that are produced for household consumption could reasonably be sold, the value of the goods needs to be included in economic activity statistics. While the fish may have been caught for a family’s own consumption, it is assumed that it could have been sold, and therefore it is treated as adding value to the economy. This is a significant issue in Pacific Island countries where large numbers of households rely on the harvest of marine resources for food and other uses.

Informal and subsistence employment has traditionally formed the basis of Pacific Island economic and social structure. The informal sector includes the production, home consumption, trade and marketing of surplus agriculture and marine products, handicrafts and services. A significant proportion of people's livelihood in the Pacific is still derived from informal production.



This is especially the case in islands and villages away from the main population centres where the cash economy and formal job opportunities are limited. Over 85 percent of Papua New Guinea’s population is rural based so most people are dependent on the subsistence economy of fishing, hunting and family gardens for their livelihoods.

Subsistence fishing is when local fishers catch or collect marine resources mainly for family food needs. Subsistence fishers use a wide range of inshore marine resources including many species of fish, lobsters, prawns, crabs and other invertebrates and aquatic plants. Catches may be consumed by the family or community, or sold for cash income.

In the Pacific, 70 to 80 percent of the catch from inshore fisheries is estimated to be taken for subsistence purposes.

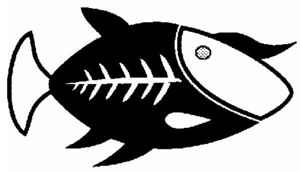
Measuring the value of subsistence production is very difficult. There are several methods that can be used, the most common being the "farm gate" pricing method. The farm gate pricing method calculates what profit a fish would have made a household if that household had sold the fish at the market instead of eating it.

Collecting catch data from widely distributed fishing communities is time consuming and impracticable for the often understaffed fisheries agencies. In PNG, as in most countries, census data combines farming and fishing together. Data is collected on “farming/fishing for food and money” and farming/fishing for subsistence only. This makes it difficult to measure the contribution of fishing to the formal or informal economy. National Statistics Office data for 1994 showed that 23% of rural households were engaged in catching fish, 60% for their own consumption, and 40% for both their own consumption and for sale.

Pacific Island governments recognise the importance of supporting the subsistence sector and enhancing its productivity, as it supports the majority of Pacific people. Subsistence fishing and informal employment make important contributions to household food security (by providing protein for the family) and economic security (by providing some cash or goods through sale or barter).

11.2 Fishing and customary marine tenure

For centuries customary systems of community decision-making have been successful in regulating the use of land and marine resources by individuals and the community in Papua New Guinea. Custom has been the basis of conservation by resource owners and has helped communities avoid resource depletion and scarcity. In the past few decades communities in rural PNG have been under pressure to become part of the cash economy. This has resulted in a gradual decline in the traditional pattern of resource use and management and, in some cases, has led to the over-harvesting of some resources. Traditional regulation of marine resources or areas can sometimes conflict with changing ideas in fishing communities regarding the value of marine resources.



The Fisheries Management Act (1998) gives customary resource ownership full recognition. However, as customary rights are unwritten and boundaries are not drawn, it is very difficult for communities to now maintain control over those rights.

Customary owners can try to use two means to maintain their rights and get some advantage out of the increased commercial value of some resources. They can limit access to their territory, or claim royalties for resource use. Often, customary rights are only enforced when a resource is exploited for money, not subsistence.

In some areas resource owners are now mapping their boundaries to give them more legal recognition. Some form of traditional, legal or assumed control of fishing areas is generally needed for communities to assume management of those areas. This will be covered in greater detail when considering the process of community-based fisheries management.

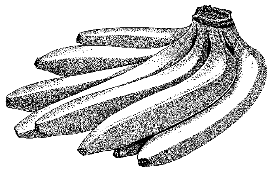
11.3 Seafood and nutrition

Nutrition is about the study of food, its nutrients and how the body uses them; and about making wise choices about what we eat. The body needs a diet of the nutrients in the right amounts.

Adequate nutrition depends on eating meals that supply enough of all nutrients. A balanced diet is one where the proper amounts of the right types of foods are eaten at regular intervals. Seafood is an important part of a healthy diet and contains protein, a little fat and some important minerals.

Foods for building strong bodies are particularly good sources of protein, which is important for growth, reproduction, maintenance and repair. These foods include fish and seafood, meat and chicken, eggs, nuts and seeds, milk, yoghurt and cheese. Proteins are essential for building and maintaining muscles and other tissues. Children require more protein in their diet (per kilogram of body weight) than adults because their bodies are still growing.

Foods for protection are particularly rich in vitamins and minerals that help protect your body from infection and sickness. Protective foods include all fruits, vegetables and sea plants.



Foods for energy include foods that are rich sources of energy. The nutrients that provide the body with most of its energy are fats and carbohydrates. The body stores these, so that energy is available all the time. While fats are a more concentrated source of energy, carbohydrates provide the body with most of its energy. Foods that contain a lot of carbohydrates include taro, yam, potatoes, bread and rice.

Eating too much fat is linked with heart disease and contributes to obesity, especially when combined with a lack of exercise. Foods that contain a lot of fat include butter, margarine, oil, and coconut cream.

Good nutrition means eating the right amounts of food chosen from the three food groups outlined above. Fish and other seafood are excellent sources of protein, vitamins and minerals and most kinds are low in fat. Protein from seafood is of very high quality and easily digested by the body. Fish in particular is very good for children. Fish is usually lower in fat than meat.

Seafood has always been an important source of food for Pacific Island people. The great variety of fish, shellfish, other sea creatures and sea plants obtained from reefs, lagoons and surrounding seas, provide people with protein and many other important nutrients needed for health and physical development. The world average per capita seafood consumption is around 13 kg — in the Pacific Islands it is estimated to vary from around 20 kg per year in larger island countries such as Papua New Guinea, to over 200 kg per year in the low-lying coral atoll nations such as Kiribati. These figures include locally harvested fish and invertebrates as well as imported seafood products.

Imported foods have now replaced some of the more nutritious foods obtained from the sea. Fresh fish is replaced by convenience foods such as tinned fish, imported fatty meats and rice. This has contributed to an increase in lifestyle diseases such as diabetes and heart disease among Pacific Islanders.

Many foods imported into Pacific countries are high in fat and low in essential nutrients. Some diseases such as diabetes, hypertension, stroke and heart disease are linked to the increased consumption of refined and processed foods such as white flour, white rice, tinned meats and packet noodles. Coastal communities need to be aware of the importance of protecting marine resources so they and their children can continue to enjoy the benefits of fresh seafood in their diet.

11.4 The role of women in fisheries

When considering fishing in the Pacific Islands people often think of fishing from canoes or boats, spear fishing, diving for giant clams and sea cucumbers, and other activities traditionally undertaken by men. The collection of seafood from the reefs and mangroves, the use of handlines and nets in shallow waters, and the preparation and sale of fish and shellfish have often been overlooked as fisheries activities by researchers and training providers. This has affected the way the fisheries sector is supported, both nationally and regionally, and the manner in which management and conservation of marine resources is approached.

In most countries fishing offshore with boats has been the domain of men while women have concentrated their activities on the inshore areas, collecting a wide variety of species from the reef and inshore area. Separate fishing roles and areas for men and women reflect community and family obligations of both. Women and children collect from the inshore areas, often as a way of supplementing the diet when the weather is too rough for the men to go out in their boats. By gleaning the reef, they can stay close to the village and not neglect other necessary tasks such as gardening and the preparation of food. Men on the other hand often fish from boats or canoes and are away from the village for much longer time periods.

In PNG, fish and invertebrates (marine and freshwater) are an important part of the diet and economy, and women's involvement in harvesting, processing and marketing is substantial.

Women's harvesting activities in PNG are mainly confined to shallow inshore areas, with an emphasis on invertebrate collection. Although information on subsistence production is scarce, the collection of invertebrates, both commercially (beche-de-mer as well as trochus and other shellfish) and for subsistence purposes is thought to exceed finfish harvesting. Women catch a substantial proportion of the annual catch weight of marine resources, reported in some studies as more than 25 percent, and are dominant in the processing and marketing sectors.

Women’s harvesting activities provide regular and affordable protein for their families, and supply cash through their sale at markets. The species that women collect, and the areas they collect from, are some of the most overexploited in the Pacific. Women’s harvesting activities are important for household food and economic security, but they also have an increasing impact on inshore resources. Despite this, women’s involvement in fisheries has often been overlooked by national and regional policy makers, and women are often not consulted or informed about fisheries management issues or plans. Successful fisheries development and management needs to deal with the entire community involved in harvesting, processing and marketing marine resources. Continuing to overlook the role of women will make it impossible to sustainably manage the inshore resources many communities are so dependent on.

The question that needs to be asked by those responsible for fisheries development and management is "Who are the target groups for fisheries development and management?" If fish market operators are predominantly women, seafood handling training should include them. Inshore fisheries management initiatives should include species and areas used by women, and women need to be involved in the planning processes and included in awareness programmes. National and regional fisheries agencies and private enterprises are beginning to see that sustainable and equitable development of the fishing industry means both men and women need to be involved in project planning, be given access to relevant training opportunities, and be involved in management initiatives.

12 DIFFICULTIES FACED BY GOVERNMENT IN MANAGING SMALL-SCALE FISHERIES

12.1 PNG - physical characteristics

There are many factors contributing to the difficulties facing government in trying to manage all the fisheries in PNG; in particular, the management of local small-scale commercial, artisanal and subsistence fisheries. One of the major constraints to effective fisheries management is the sheer size and complexity of the area and the fisheries.

The island of New Guinea is the largest tropical island in the world. The eastern portion of the island, Papua New Guinea, comprises the mainland and the archipelagos, consisting of more than 600 islands. The land area is some 462,000 sq km. PNG has a coastline of over 17,000 km. The ocean area including the EEZ, territorial and archipelago waters is about 3.1 million sq km. PNG also has extended mangrove systems and marshland. There are fast and slow flowing rivers and some 500 lakes of all sizes.

The coastline and offshore archipelagos have an extensive shoreline and present a great diversity of costal types and marines environments. The Gulf of Papua is characterised by large deltaic areas of mangroves swamps and mudflats, while the north coast and the high islands coastal are typified by fringing coral reefs and narrow lagoons.

Some of the smaller islands clusters lie adjacent to extensive submerged reefs systems or broad shallow lagoons. Some provinces including Western, Gulf, Central (including NCD), Oro, Morobe, Madang and East Sepik and West Sepik have extensive freshwater systems.

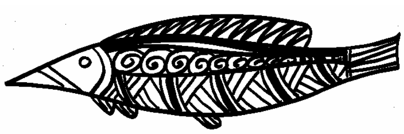
12.2 Political and institutional characteristics

PNG has a decentralised system of government. It has three levels of governments comprising the national, provincial and local level government. These are the levels of governments that can make laws. There are 20 provincial governments (including 19 provinces and the National Capital District); 89 administrative districts, 284 local level governments and 6,352 wards. Fifteen of the twenty provinces are coastal or maritime provinces.

The National Fisheries Authority was established under the Fisheries Management Act (FMA) of 1998. NFA consists of the National Fisheries Board and the Authority. The principal function of the Board is to establish management plans and issue fishing licences and other licences. NFA makes recommendations to the Board on matters relating to the proper management of PNG's fishery resources such as the issuance of licenses and implements management plans and licence conditions.

The Fisheries Management Act, which established NFA, also defines its roles and responsibilities. The NFA is mandated to manage all the fisheries resources in the fisheries waters of PNG. It is responsible for most of these fisheries including local fisheries such as beche-de-mer and the red snapper fisheries.

The FMA, however, does not address the taking of fish for personal consumption, sport or recreational fishing, or customary and artisanal fishing. It also has no adequate provisions for consultations with fishermen and the stakeholders, except through the interpretation of the powers of NFA.



In 2001, when NFA became a Non-Commercial Statutory Authority (NCSA) staff levels were cut from some 330 to around 66. One of the implications of this was that functions such as research and extension services were scaled down. As a NCSA, NFA collects revenue on behalf of the government. It retains some of the revenue to fund budget and cash flow needs and pays the balance to the Government. One of the major roles of NFA is to improve on the collection of resource rents from foreign fishing interests on behalf of the government.

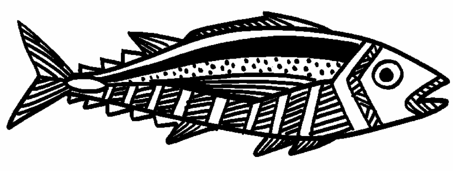
PNG citizens operating in the local fisheries such as lobster, BDM and other reef fisheries are charged minimal to nil licence fees. Usually the licence fees collected from these local operators are not adequate for management and monitoring of these fisheries.

12.3 Research and monitoring constraints

PNG's small-scale fisheries reflect the diversity and extent of the country's coastal marine environments. Along the mainland and high island coasts and in smaller island communities, fishing activities include harvesting of the reef flats, spear fishing, shallow water handlining from dugout canoes, netting, and trapping in the freshwater reaches of large rivers. Subsistence harvesting is perhaps the most important component of PNG's domestic fisheries. Fish is either consumed, bartered, or sold for cash in the subsistence economy and it has been estimated that some 250,000 to 500,000 people participate in the subsistence fishery with landings of approximately 26,000 metric tonne annually.

There is very limited national capacity to actually monitor the true nature of fishing effort and fish landings. Periodic surveys in some locations can provide snapshot information as a basis for estimates of actual fishing effort and fish consumption but there is no standard procedure at the provincial level for regular surveys or information collection.

NFA is the national fisheries management agency and, in order to carry out adequate management functions, the Authority needs to access a wide range of fisheries information. This information can be variously gathered from Provincial level fisheries departments, university researchers and NGOs.



However, at the present time, there is inadequate collection, coordination and analysis of key fisheries information as required for policy development and management decision making.

12.4 Surveillance and enforcement

Responsibility for surveillance and enforcement is vested with NFA and shared with the Department of Defence. For large fisheries there is a regional satellite tracking system called VMS (vessel monitoring system) which tracks licensed vessels on a daily basis. Sea and air patrols also help to monitor the extensive EEZ waters.

The challenge of surveillance and enforcement for small scale fisheries is a significant task. The revenues generated from licence fees for small-scale fisheries are not sufficient to fund adequate surveillance and enforcement of those fisheries.

Regulations and rules will only work where there is a capacity to enforce them. In isolated areas, this capacity is very limited and it is difficult to manage the enforcement of fisheries rules. Provincial fisheries administrations do not have the institutional capacity to monitor small-scale fisheries and carry out research functions.

It is increasingly apparent that there needs to be other means or ways to monitor and enforce fisheries and management plans at small-scale fisheries level.

In many countries in the Pacific Islands, there is an increasing focus on having communities manage their fisheries resources. Monitoring and enforcement become community level activities with fisheries rules being set from within the community, rather than from outside.

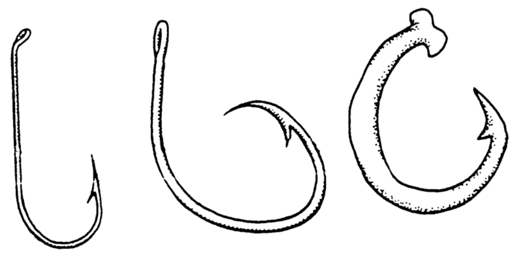
12.5 Summary

Contributing factors to the difficulties faced by government in managing small-scale fisheries include:

- The physical characteristics of the country that make it impossible for government to manage all the fisheries, especially small-scale fisheries, from Port Moresby;
- The decentralised government system is not adequately resourced in relation to funding and staff to carry out management related activities at the provincial level;
- Funding collected from licence fees from small-scale fisheries operators is not adequate to fund research, surveillance and enforcement at the provincial level.

There is increasing acknowledgement of the idea that local level fisheries management can and should be undertaken by communities.

This manual is designed to have the reader better understand the dynamics of fisheries and marine resources and the importance of fisheries management. Ideally the manual will prove to be a useful tool in working towards empowering communities to be more involved in the consideration of resource management options and strategies.



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