Environmental Education Module

The Oceans and Coastal Areas and their Resources

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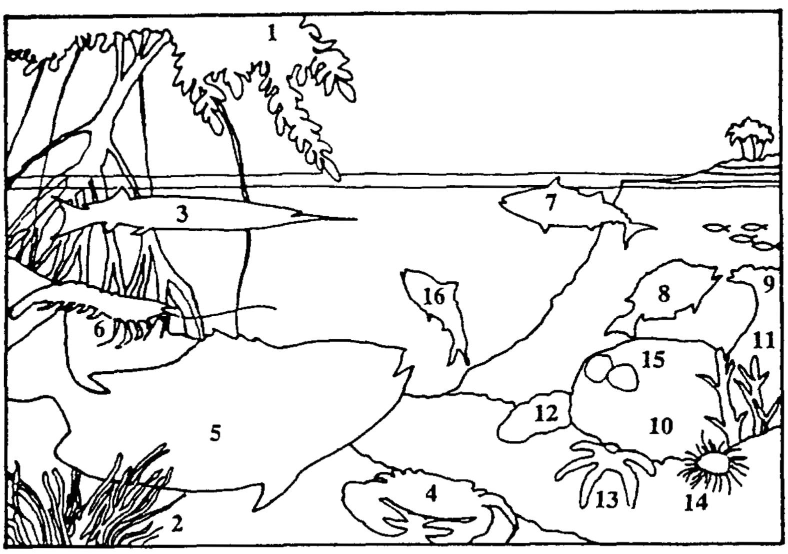

Key to cover drawing:
1) mangrove
2) seagrass
3) garfish
4) mangrove crab
5) snapper
6) shrimp
7) tuna
8) parrotfish
9) table coral
10) brain coral
11) staghorn coral
12) sea cucumber
13) sea star
14) sea urchin
15) serpulid worm
16) sardine

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International Environmental Education Programme (IEEP)

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ACKNOWLEDGMENTS

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EPD-95/WS-3

The Oceans and Coastal Areas and their Resources

CONTENTS page

INTRODUCTION: HOW TO USE THIS BOOK

This book is designed for teachers. Each topic includes,

a) descriptive text with background information for teachers, and,

b) an accompanying page (enclosed in a black border) for presentation to students.

The student information enclosed in borders includes minimal text and relies heavily on illustrations. It is designed to be photocopied either on a transparent sheet for use on an overhead projector, or on plain paper as a student handout.

Most sections include practical exercises and sample questions for students. Although teachers are encouraged to emphasise local issues, it is desirable to convey a world view for each topic. The degradation of coastal areas and the marine environment, as well as the overexploitation of coastal resources, is a global problem.

Some educators may be in a position to introduce aspects of environmental education into subjects that students are currently studying. The material presented in this book, or parts of it, may be included in subjects such as general science, political science, sociology, ecology, biology, geography and other subjects. This multidisciplinary approach may be the most convenient way to provide students with exposure to environmental topics in the short term. Wherever possible however, it is desirable to introduce a separate environmental education subject into high school curricula. This interdisciplinary (single subject) approach provides environmental education with discipline status, even though input from other areas is required, and is the most likely way to provide the subject with the legitimacy that it deserves.

Whichever approach a particular school uses to introduce environmental education, the topics in this book will take students beyond a study of ecology, to include relationships between ecological concepts and environmental issues, as well as environmental problem solving. The objectives of this book are aimed specifically at the secondary level, thus a teacher might well be pleased if students obtain an increased awareness of environmental issues. Such an awareness may produce future citizens who are more environmentally responsible individuals. Introducing students to environmental subjects at an early age is most important, as young people are particularly receptive to learning environmental values and behaviour. In addition, information and values communicated to the young can be a way of raising the awareness of parents and the general community. Even at this early age, however, it is desirable to introduce social perspectives and debate, and to extend the topics to include environmental problem solving. The teacher should, wherever possible, introduce exercises based on real problems and discuss possible solutions. Problem solving should have a community focus. Students should be encouraged to discuss ways in which the community can be made more aware of environmental issues, and ways in which people can take part in defining their own environmental concerns and in providing solutions. Wherever appropriate for young students, the topics in this booklet are extended to deal with environmental investigations, evaluations and discussions of remedial actions. For example, the balance between the need for development and the need to protect the marine environment is stressed in the section entitled "Coastal Development and Sources of Pollution".

Some students may be encouraged to further their studies in order to take up a career involving the protection of the marine environment and in the management of marine resources. Such careers can involve practical skills, such as surveying, seamanship and diving, as well as intellectual skills, such as extension work, legal debate and analysing data with a computer. Perhaps it is this mixture of active open-air tasks and interacting with people, as well as stimulating office or laboratory work, that makes any marine career so interesting. The entry to any worthwhile career requires some specialised training; some careers involve lengthy academic studies, while others involve a shorter time of practical training. Whatever the area of interest, specialised training will allow the student to work with other qualified and highly-motivated people in surveying, developing, and managing marine ecosystems and resources.

In the past many coastal areas and resources have been managed within a framework of traditional knowledge which has accumulated over many hundreds of years. Communal groups such as villages, have normally had customary or traditional rights to exploit resources and to fish in adjacent coastal areas, including lagoons and coral reefs. People from the local communal groups were small in number and were mindful of customary methods of conserving the coastal environment and stocks of fish. In parts of the Fiji Islands, for example, a particular word "kaiwai" is used to describe coastal or sea people who keep and use the marine environment wisely.

Traditional management methods, however, are being eroded with increased population sizes and a trend towards money-based economies and commercial fishing. The annual commercial catch from world fisheries is almost 100 million tonnes. Seafood is a major food item in many countries, where subsistence fishing, the catching of fish to eat rather than to sell, results in a total catch that is often several times larger than that from commercial fishing. In coastal regions of southeastern Asia and in tropical islands, for example, seafood consumption is often over 50 kg per person each year (compared with a mean of about 12 kg per person for the world), and in low-lying coral islands, where soils are too poor to support intensive agriculture, seafood consumption is often over 150 kg per person per year.

In the past, when populations were small, and fishing methods were less efficient, catches made by one person had very little effect on catches made by others. But the human population and its demand for seafood have grown beyond that which can be supported by finite resources. In addition, there are other claims on the marine environment from recreation, development and industry. The dilemma is, that as demand for fisheries resources is increasing, the ability of the marine environment to sustain them may be decreasing. The freedom to catch fish, or to use the marine environment, without control is now more than likely to be at the expense of someone else's freedom to do the same thing. Some of these freedoms must be sacrificed to allow the continuing use of the marine environment and its resources by present and future generations.

The use of natural resources such as the cutting down of coastal trees or mangroves, or the harvesting of fish, requires careful control to avoid overexploitation. The renewability of natural resources depends on our ability to see that too many marine animals and plants are not harvested, and that the environment on which they depend does not deteriorate.

Michael King and Sarah King,
Western Samoa.
1995

OCEANIC ECOSYSTEMS

Most texts on marine science begin by stating that over 70% of the planet earth is covered with water. With many terrestrial resources under threat or depleted, it is tempting to view this large area of sea water as a last frontier; an area in which to extend the search for further resources.

The list of potential resources from the sea includes the extraction of gold dissolved in sea water, manganese nodules from the deep-sea floor, and pharmaceuticals from marine plants and animals. Minerals are present in sea water and sea-floor sediments in huge quantities, and ostensibly they are there for the taking. The problem is that the requirements in both energy and technology for their harvesting are huge. The sea does not give up its riches easily or cheaply.

Apart from offshore fishing, particularly for tuna, the open seas have remained relatively free of exploitation. From a biological point-of-view most of the planet's huge area of sea is the equivalent of the deserts on land. Like terrestrial deserts, most of the open sea supports only a small number of highly specialised plants and animals. Unlike the narrow band of coastal waters, which contain large numbers and a great variety of fish, the open ocean is generally unproductive, and oceanic fish, such as tuna, are generally restricted to particular areas which are unusually rich in nutrients.

The introduction of new types of boats and fishing gear have not only increased pressure on existing resources, but allowed access to previously inaccessible stocks of fish, even those in distant waters and far from land. Just as inshore fisheries resources are under increasing pressure from coastal fishers, the offshore resources are in increasing demand by countries which operate large, ocean-going, fishing vessels.

The problems are - Who will care for the fish of the open sea? Who will ensure that migratory fish are not overexploited as they move through the waters of many different countries? Who will prevent the numbers of oceanic fish being reduced to such an extent that the remaining adults are unable to produce enough young to maintain the stock?

The renewability of fisheries resources depends on our ability to see that too many fish are not caught, and that the environment in which they live does not deteriorate. This implies that a fish stock has to be managed, and the marine environment protected. The attitudes, particularly of more industrialised countries, that the fish of the open sea can be fished without restraint, and that the sea is a convenient dumping area for the wastes of society, have to be changed.

This section provides a scientific introduction to the oceans, in particular their physics and biology, as a means to gaining an understanding of oceanic ecosystems. How is it possible to generate electricity from temperature differences in the ocean? Why there are such large differences in the distribution of marine life? Why are there many different species of fish near the coast and very few in the open sea? Why is it that small areas such as those off the northwest coast of South America are so rich in fisheries resources, yet other oceanic areas are so barren. To answer these questions, however, it is first necessary to examine the characteristics of oceans.

1. OCEANS and THE SEA FLOOR

BACKGROUND

The three major bodies of water on the earth are the Atlantic, Indian and Pacific Oceans. The Pacific Ocean, the largest and deepest, constitutes about 43% of the oceanic area of the world, and is larger than all land areas combined. The Indian and Pacific Oceans are joined in the tropics to the north of Australia, and form a continuous region, the Indo-Pacific. Because of this, marine life in the Pacific Ocean has greater similarities with that of the Indian Ocean than with the Atlantic Ocean.

The outer crust of the earth, the lithosphere, is made up of a number of plates which float on a deeper layer of molten material, the mantle. This is somewhat analogous to pieces of a cracked egg shell which float on and cover the fluid beneath. The lithosphere plates are moving very slowly, either towards or away from each other. Where the plates are moving apart, the liquid mantle flows upwards and solidifies to form submarine ridges and, sometimes, islands. Where the plates move towards each other, they may either fold upwards to form a mountain range, or one plate may be forced below the other to form a deep oceanic trench.

The boundaries between the lithosphere plates (shown in overhead/handout 1) are unstable areas where earthquakes may occur as plates move against each other. The deepest parts of the ocean occur in the trenches formed where plates are colliding (eg. the Tonga and Marianas trenches in the Pacific Ocean). The average depth of the ocean is about 3.5 km and the deepest areas, in the Marianas and Philippine trenches, are over 11 km deep. A generalised profile of the sea floor is shown in overhead/handout 1.

OBJECTIVES

The student will be able to a) appreciate the vastness of the world's oceans and their physical characteristics as a background to understanding the ecological importance of the seas, b) name the major oceans of the world, and the components of an oceanic profile, and c) describe how oceanic trenches and ridges are related to the movement of tectonic plates on the earth's surface.

METHODS

Overhead/handout 1 should be used to show the geographical position and names of the world's seas. Plate tectonics should be explained before considering the components of the ocean floor profile shown. Access to a large relief map of the floor of one of the major oceans would be useful.

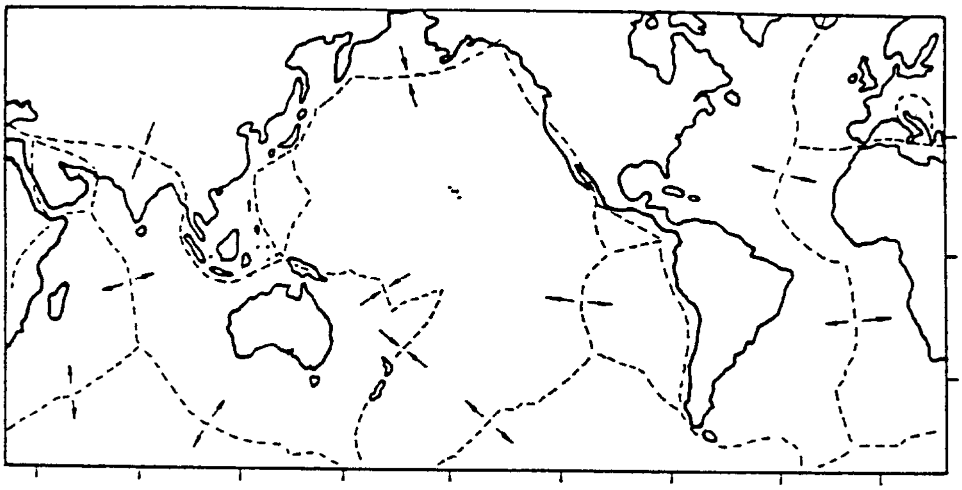
ACTIVITIES/ASSESSMENT

Students should be asked to add the names of the world's oceans to the map (with names blanked out) shown in overhead/handout 1.

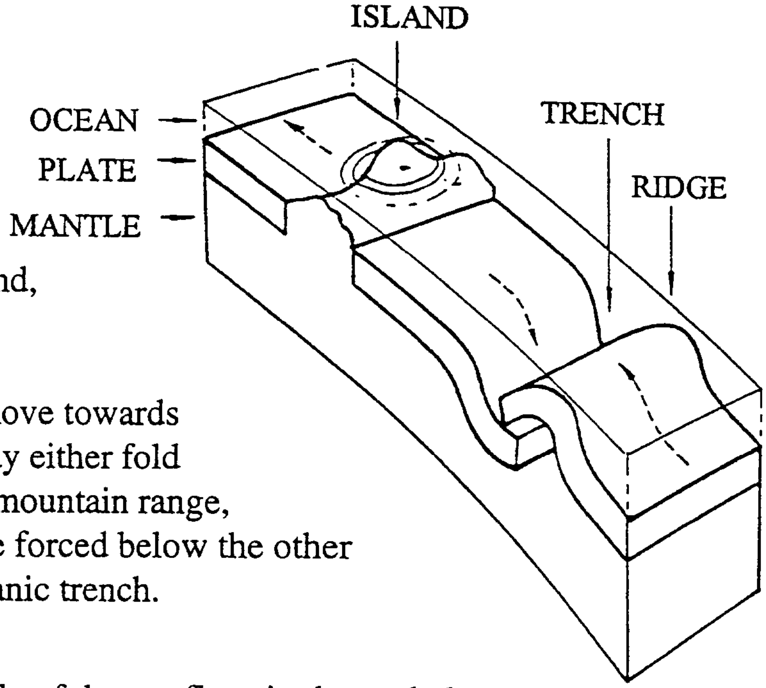
Students should be asked to draw a diagram of a generalised sea-floor depth profile, and discuss how the profile is associated with the movement of tectonic plates. The depths off local coasts should be taken from marine charts, and a depth profile drawn on graph paper using an appropriate scale for depth and distance from the coast.

OVERHEAD/HANDOUT 1

OCEANS and the SEA FLOOR



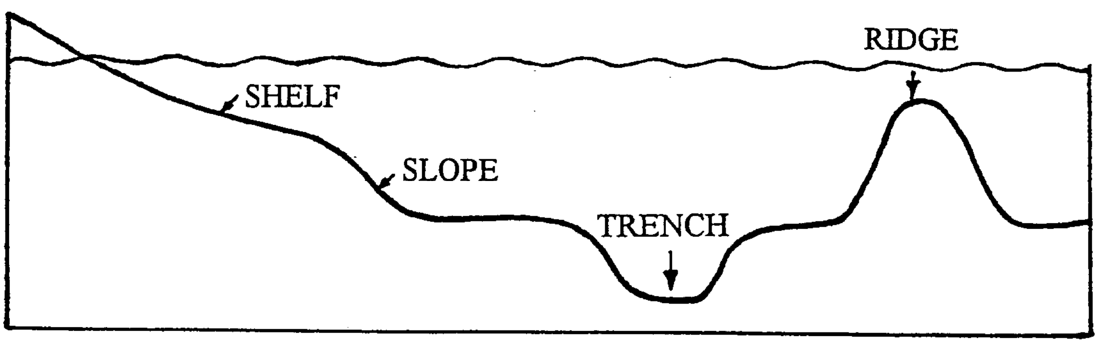
Margins of lithosphere plates (movement of plates shown by arrows).



Where the plates are moving apart, the liquid mantle flows upwards and solidifies to form submarine ridges and, sometimes, islands.

Where the plates move towards each other, they may either fold upwards to form a mountain range, or one plate may be forced below the other to form a deep oceanic trench.

A generalised profile of the sea floor is shown below.



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The Oceans and Coastal Areas and their Resources. M.King and S.King.
UNEP

2 .WINDS and CURRENTS

BACKGROUND

Winds are generated across the earth's surface by pressure differences in the atmosphere. Bands of high and low pressure on the earth's surface are shown in overhead/handout 2. The winds blowing from high to low pressure areas across the earth create forces on the sea's surface in the direction of the wind. The surface currents created, however, do not continue to follow the wind's direction, but are diverted by island chains, continents and forces created by the spinning earth.

The rotation of the earth towards the east imparts an easterly momentum to all objects on the earth's surface. As the diameter of the earth is greatest at the equator, objects here will have a faster easterly motion than in higher latitudes. At the equator, an object on the surface will complete a circumference of the earth in 24 hours, and will therefore be travelling at approximately 1700 km/hour. If the object was at 45 degrees north or south, where the circumference of the earth is less, it would only be travelling at about 1200 km/hour.

An object such as a "slab" of water, driven to the north from the equator by the wind, would still be carried towards the east at the speed of the earth's surface at the equator. Therefore, instead of travelling due north in a straight line, the slab of water would curve to the right. Similarly, in the southern hemisphere, a slab of water moving in a southerly direction from the equator would curve to the left. This force, known as the Coriolis effect, causes bodies of moving water to rotate in a clockwise direction in the northern hemisphere, and in an anti-clockwise direction in the southern hemisphere.

OBJECTIVES

The student will be able to a) appreciate the general movement of currents across the surface of the world's oceans, b) name the major surface currents of the world and their direction of flow, and c) understand the infuence of the Coriolis effect on the direction and rotation of currents.

METHODS

The mechanism of the Coriolis effect should be explained using a globe of the earth. A useful analogy to use involves the Coriolis force influencing the path of a rocket fired directly at a target north from the launching position on the equator. The rocket will land to the east of its target because of the Coriolis effect. Overhead/handout 2 should be used to show the geographical position, name and direction of the major surface currents of the world's oceans.

ACTIVITIES/ASSESSMENT

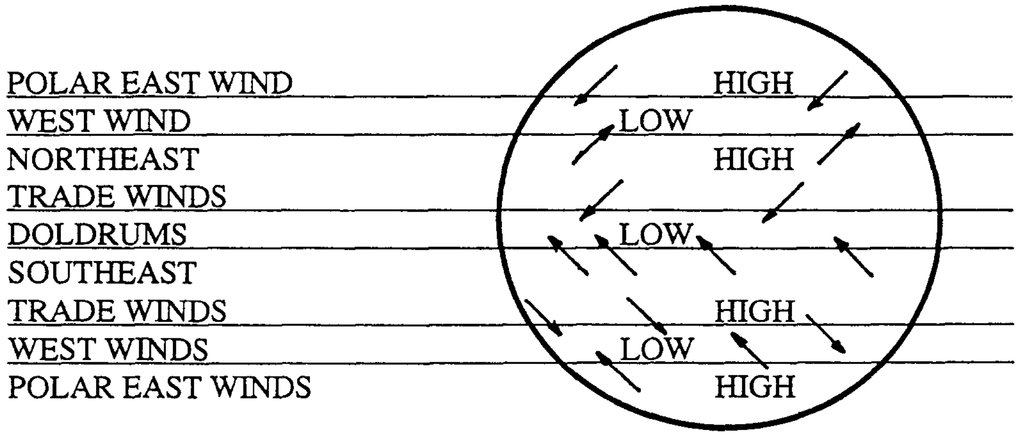
This question may be altered to include currents of local importance. Indicate the approximate direction of the following currents as either N->S, S->N, W->E, or E->W.

Humbolt current (Pacific Ocean)	....
North equatorial current (Pacific Ocean)	....
Benguela current (Atlantic Ocean)	....
Equatorial counter current (Indian Ocean)	....

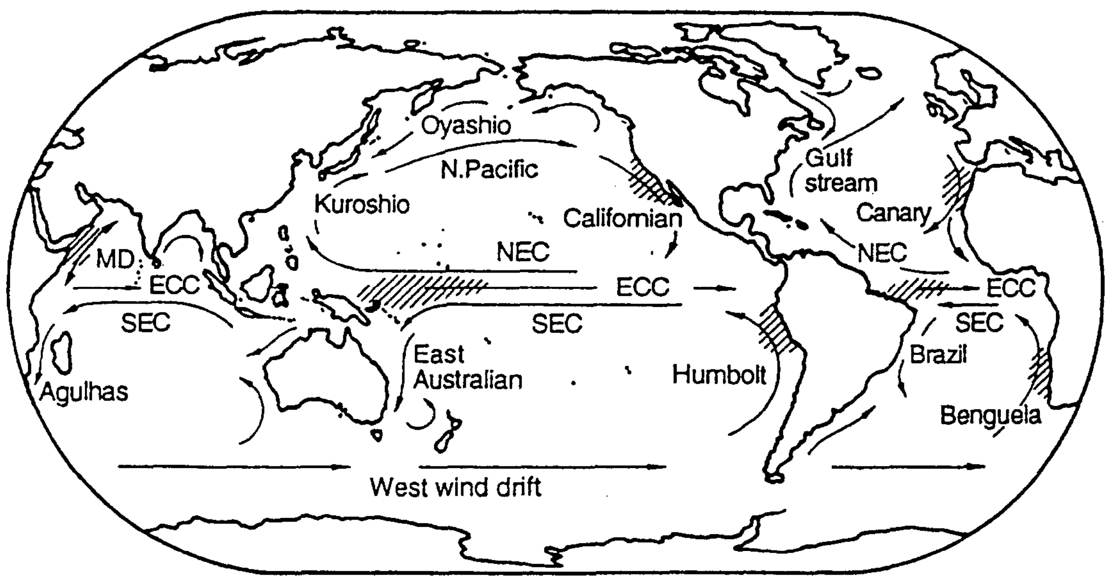
OVERHEAD/HANDOUT 2

WINDS and CURRENTS

The winds blow from high to low pressure areas across the earth and create forces on the sea's surface in the direction of the wind.



The surface currents created, however, do not continue to follow the wind's direction but are diverted by island chains, continents and the Coriolis effect caused by the spinning earth (the shaded areas are upwellings - see section 6).



SEC = South Equatorial current: NEC = North Equatorial Current:
ECC = Equatorial counter current: MD = Monsoon Drift

3. THE SUN, MOON and TIDES

BACKGROUND

The water covering the earth is under the attractive forces of both the sun and the moon. The strength of these forces is related to the mass of the body and its distance from earth. Although the sun has the larger mass, its great distance from earth means that it has relatively little affect on tides. In spite of the moon's smaller mass, its proximity to earth means its attractive forces are much stronger than the sun's, and provides the major influence on tides.

In the polar view of the earth (overhead/handout 3), there are two tidal bulges of sea water. The moon pulls the water away from the earth on the nearest side, and pulls the earth away from the water on the opposite side. Thus two areas on the earth's surface are directly under the bulge of water, and are experiencing high tides, at any one time. As the earth is rotating, each point on the earth's surface will have two high tides and two low tides every 24 hours. This sequence of tides may be different in some areas due to the influence of coastal formations including headlands and bays.

Although the sun's gravitational forces are only about 40% of the moon's, the sun's relative position affects the tidal range (the difference in height between high tide and low tide). When the moon and the sun exert gravitational forces in a straight line, the tidal range is the greatest (spring tides); this occurs around the time of new moon (when the shadow of the earth hides the moon totally) and the time of full moon (when the moon is visible as a full sphere). When the forces of the moon are at right-angles to those of the sun, the tidal range is the lowest (neap tides). This occurs around the time of the first and last quarter of the moon (when the light of the sun illuminates one half of the moon). As the moon circles the earth each lunar month of 28 days, there are two neap tides and two spring tides during this period.

OBJECTIVES

The student will be able to a) understand the causes of tidal movements as a background to understanding the ecological importance of tides in marine ecosystems, and b) describe the mechanisms involved.

METHODS

Overhead/handout 3 should be used to show the effect of the moon and sun on tidal movements. The teacher should stress that many marine animals depend on the tidal movements of seawater.

ACTIVITIES/ASSESSMENT

As a project, groups of students may use a wooden pole graduated in 1 cm intervals and set in the substrate at the low tide mark to record the level of the sea at half-hour intervals. The results should be graphed with relative water level on the Y-axis and time on the X-axis.

If local tide-tables are available, students should graph high and low tides over one lunar month (to obtain a graph similar to that shown in overhead/handout 3). Students could also make a list of local intertidal animals.

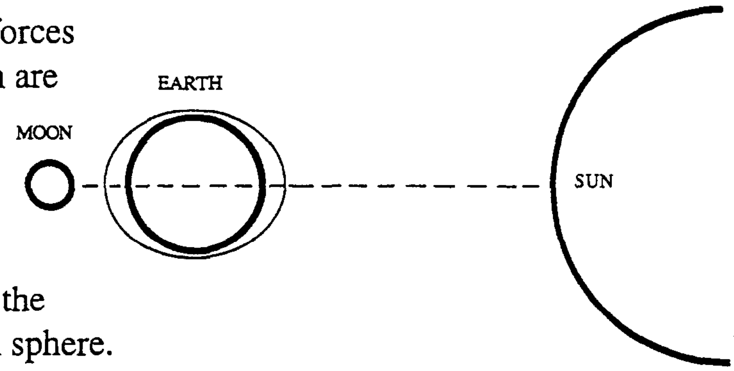
OVERHEAD/HANDOUT 3

THE SUN, MOON and TIDES

The water covering the earth (indicated by the fine line above the earth's surface) is under the attractive forces of both the sun and the moon. Thus two areas on the earth's surface are directly under the bulge of water, and are experiencing high tides at any one time.

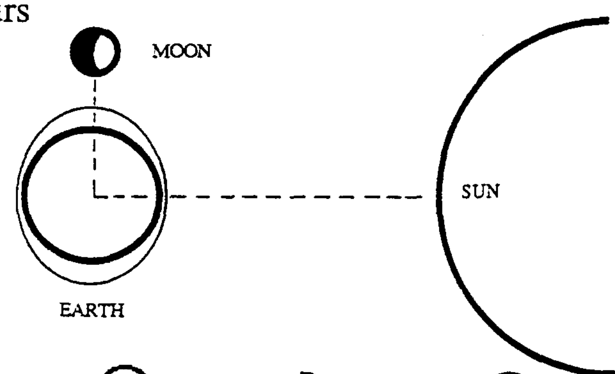
SPRING TIDES

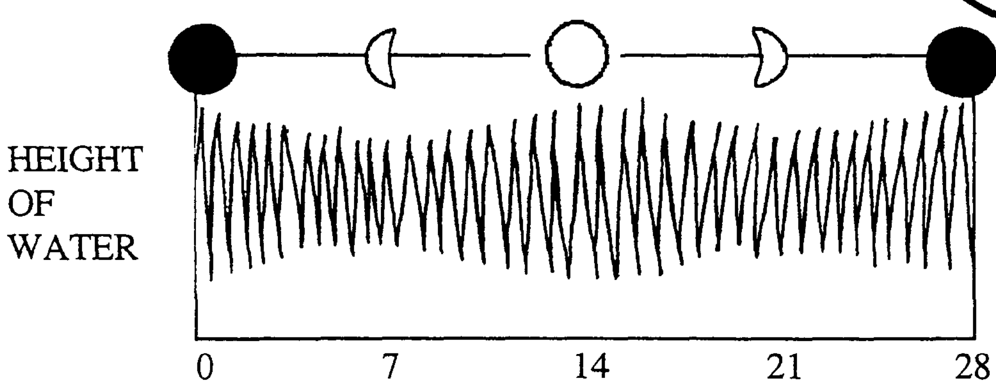
A large tidal range which occurs when the gravitational forces of the moon and the sun are in a line at the time of, **NEW MOON** - when the shadow of the earth hides the moon, **FULL MOON** - when the moon is visible as a full sphere.



NEAP TIDES

A small tidal range which occurs when the forces of the moon are at right-angles to those of the sun, at the time of **FIRST and THIRD QUARTER MOONS,** when the light of the sun illuminates part of the moon.





High and low tides shown over one lunar month (28 days). The tidal range is greatest (spring tides) when the moon is new or full, and lowest (neap tides) at the time of the first and third quarter of the moon.

4. ENERGY FROM THE OCEAN

BACKGROUND

There have been many schemes to generate energy from the sea. Some depend on the movement of tides to drive turbines to generate electricity. Another possibility is to use the large difference in temperature between surface water and deep water in tropical regions - this is the basis of installations known as Ocean Thermal Energy Conversion (OTEC) systems. Pilot scale OTEC installations have been built in several tropical regions, and the one shown in overhead/handout 4 is based on the one built in Hawaii.

The concept of an OTEC installation is simple. Warm surface water is used to evaporate a low-boiling point fluid (such as ammonia) and the expanding gas is used to drive a turbine which generates electricity. The gas is condensed back to a liquid by using cold water pumped up from depths of about 1000 m. The liquid is then returned to the boiler where the process is repeated.

Unlike most surface waters, the water brought up from the deep in OTEC systems contains many plant nutrients. It has been suggested that this water, if released at the sea's surface, would increase fisheries productivity (in the same way as natural upwellings do - see overhead/handout 6). Alternatively the nutrient-rich water could be saved in ponds which could be used to farm (aquaculture) marine species.

OBJECTIVES

The student will be able to a) reproduce in diagrammatic form, an OTEC system, b) understand how an OTEC system works, including the physical principles involved, c) compare the environmental impact of an OTEC installation with other energy generating systems, and d) discuss the question "Why does society require so much electricity anyway?" - and ways of reducing this requirement. This sequence of increasing levels at which a subject may be presented is used as an example in the section on Syllabus Development (page 93).

METHODS

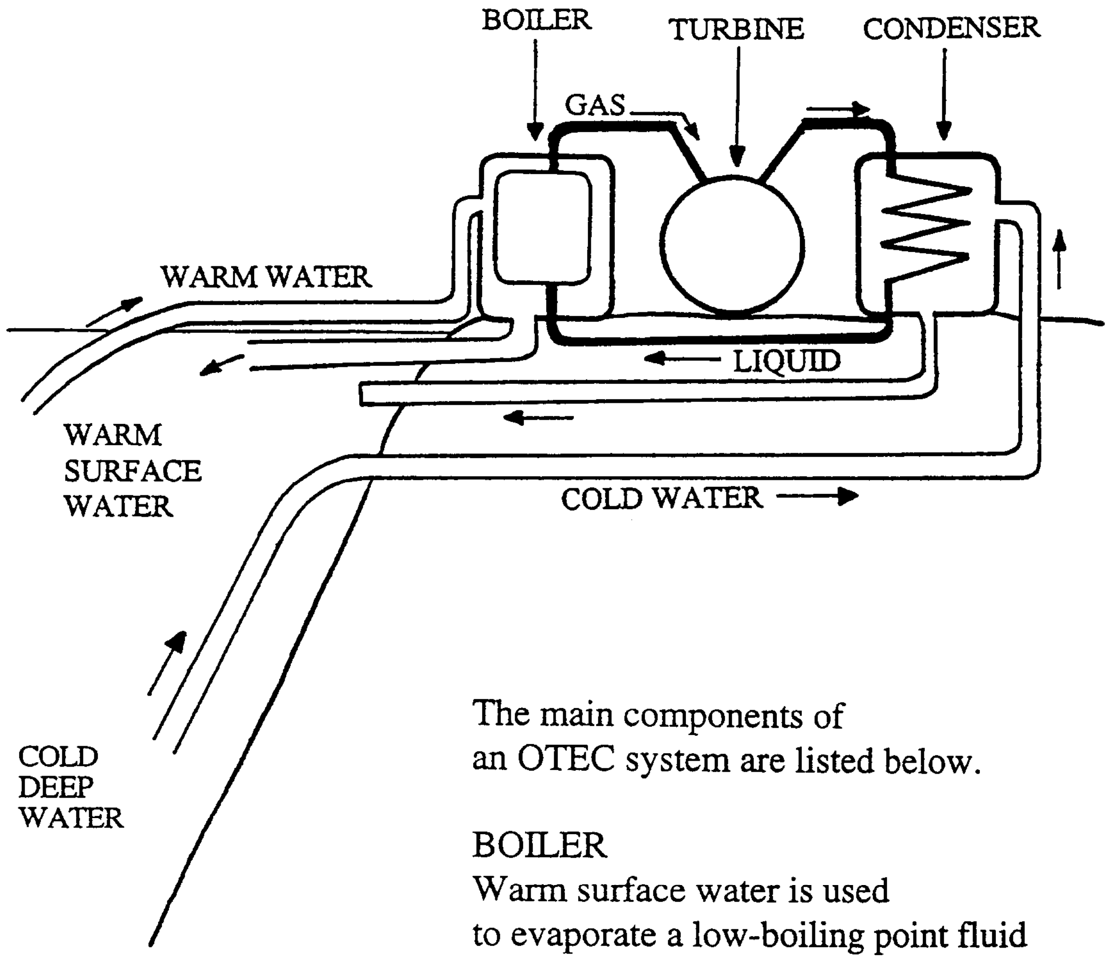
Overhead/handout 4 should be used to show the design of an OTEC system. The teacher could take the opportunity to preview the topics of thermoclines (overhead/handout 5) and upwellings (overhead/handout 6) which are associated with the operation of OTEC systems. Presentations to general science students should be expanded to include the physical principles involved in OTEC systems.

ACTIVITIES/ASSESSMENT

Students should be able to draw a diagram of an OTEC system and list the requirements for the placement of such a system. Students should be able to discuss the effects of an OTEC system on the environment and compare these with the effects of power stations which use oil to generate electricity. Other topics could include discussions on the possibility of installing an OTEC system on the local coastline, and on the possibility of using the waste water for aquaculture (the farming of marine species). At the highest level of education, students should be able to discuss why society requires so much electricity, and ways of reducing this requirement.

OVERHEAD/HANDOUT 4
ENERGY FROM THE OCEAN

An Ocean Thermal Energy Conversion (OTEC) system.



The main components of
an OTEC system are listed below.

BOILER
Warm surface water is used
to evaporate a low-boiling point fluid
(such as ammonia).

TURBINE
The expanding gas is
used to drive a turbine which
generates electricity.

CONDENSER
The gas is condensed back
into a liquid by using cold water
pumped up from depths
of about 1000 m.

5. PRODUCTIVITY OF THE SEAS

BACKGROUND

Primary production refers to the production by plants of organic material from sunlight and nutrients through the process of photosynthesis. Primary production in the open sea depends almost solely on the existence of microscopic plants, collectively called phytoplankton, which live in the sunlit surface layers of the sea.

Small floating animals, and the larvae of larger animals, collectively called zooplankton, move up into the surface layers of the sea during the night to graze on the phytoplankton. During the hours of daylight, the zooplankton move down to deeper layers, enabling the phytoplankton to increase their numbers by cell division. Small fish which feed on the zooplankton, are themselves food for larger fish such as tuna.

Like all plants, the existence of phytoplankton is dependent on the presence of sunlight and nutrients (particularly nitrates and phosphates). Phytoplankton are only found in depths down to about 50 m, as they require sunlight. In this zone, called the photic zone, nutrients will be quickly used up unless there are mechanisms for replacement (see overhead/handout 6 on upwellings).

In polar waters where surface waters are cooler than deeper waters, warm nutrient-rich water will move up into the photic zone by convection, and provide a continual source of nutrients for phytoplankton. However, if the surface waters are warmer than deeper waters, as they are in the tropics, there is no mechanism for deep nutrient-rich water to move up and replace the nutrient-depleted water of the photic zone. This is why the open ocean in tropical areas is usually unproductive in terms of marine life. There is an exception to this in particular areas where water moves up from the deep, bringing with it large quantities of nutrients. These areas, known as upwellings, are described in overhead/handout 6.

OBJECTIVES

The student will be able to a) understand basic oceanic food chains; which will provide a background to the concept of more complex food webs which is dealt with in the section on Coastal Ecosystems, and b) name the components of oceanic food chains from phytoplankton to high level carnivores.

METHODS

Overhead/handout 5 should be used to show a classical open sea food chain. The productivity of the open sea should be discussed in relation to the temperature/depth profiles shown.

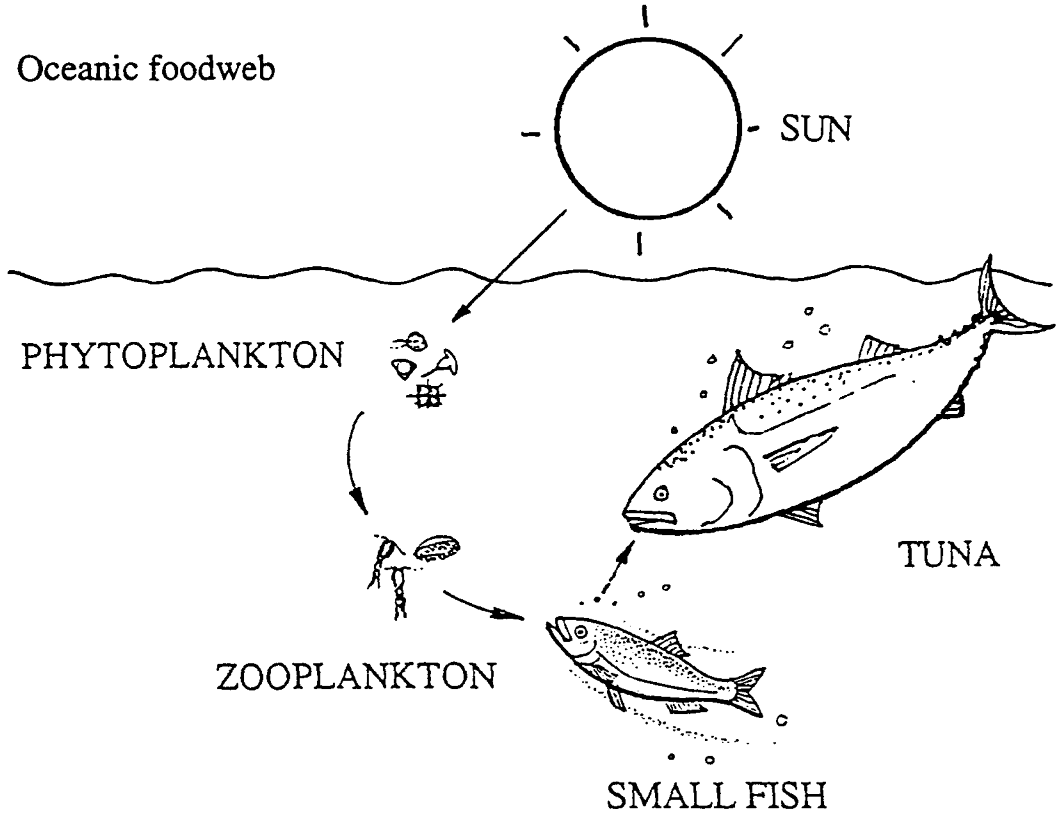
ACTIVITIES/ASSESSMENT

Biology students should be given the chance to collect, examine and compare zooplankton. A small, fine-meshed, conical net sewn onto a metal hoop may be towed through the water during the evening from the end of a wharf or jetty. The zooplankton may be collected alive in the tapered end of the net after each tow, and transferred to a container of seawater before examination under a low-power microscope; specimens should be drawn, and identified as far as possible.

OVERHEAD/HANDOUT 5

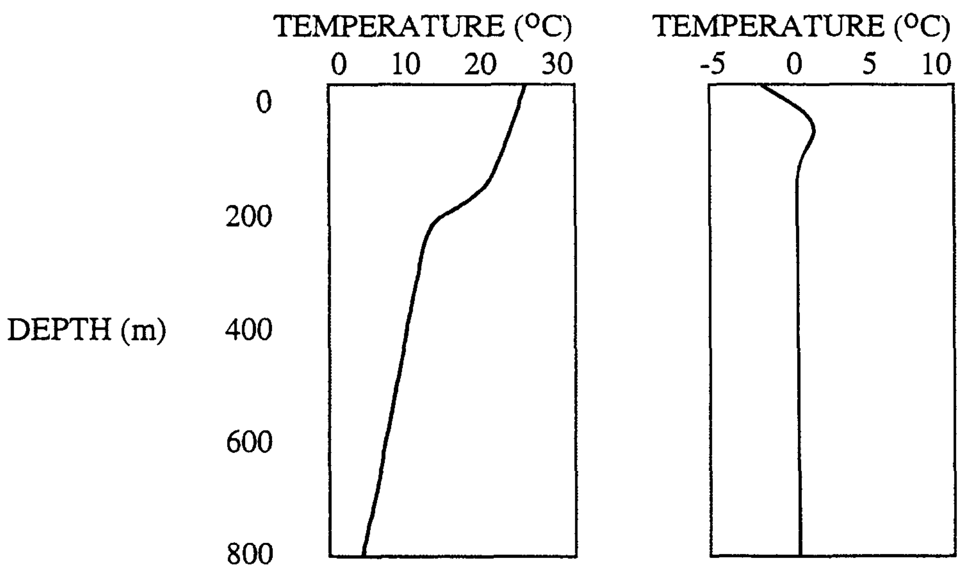
PRODUCTIVITY OF THE SEAS

Oceanic foodweb



TROPICAL WATERS
surface waters warmer than deeper waters

POLAR WATERS
surface waters cooler than deeper waters



6. UPWELLINGS and OCEANIC FISHERIES

BACKGROUND

Phytoplankton, the basis of oceanic food chains, can only grow where there are sufficient nutrients, mainly dissolved nitrates and phosphates. Most surface areas of the sea contain only small quantities of nutrients and can, therefore, support only small numbers of fish. An exception to this is in particular areas where water moves up from the deep, bringing with it large quantities of nutrients. These areas, known as upwellings, occur in several parts of the world's oceans. Major upwellings in the world's seas are shown on the map on overhead/handout 2 (with surface currents of the world).

Upwellings may be caused simply by winds blowing offshore from a continent. The forces exerted by the wind drag surface water away from the shore. This water is then replaced by deep water moving up the continental slope. A large upwelling off the Pacific coast of South America is caused by Coriolis force acting on a strong northerly Humbolt current. This force causes the current to veer away to the left, and shore line surface waters are replaced by an upwelling of deeper water. This upwelling results in rich fisheries off the coast of Peru.

An equatorial upwelling in the western Pacific results from two large currents (the north and south equatorial currents) moving apart, one northwards towards Japan and the other southwards down the coast of Australia. As these two currents move apart, deep nutrient-rich water moves up to replace surface waters in the region of the equator. Through the food chains, this upwelling results in large stocks of tuna in the waters of Papua New Guinea, the Solomon Islands and Kiribati.

The best known open sea fish are the several species of tuna, which are distributed over large areas of ocean where they hunt smaller planktivorous fish. Catches of tunas amount to over 5% of the world catch. Tuna are caught by local fishers in many sub-tropical and tropical countries, usually by trolling lures behind small boats. Distant water fishing vessels fish for tuna using pole-and-lining, long-lining and purse seining (see overhead/handout 39 and 40 on fishing methods). The relative important of different tuna species in the world catch is illustrated in overhead/handout 6. 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 life.

OBJECTIVES

The student will be able to appreciate a) mechanisms causing upwellings, and b) the role of upwellings in oceanic fisheries.

METHODS

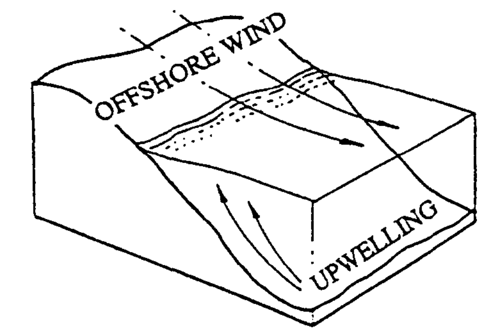
Overhead/handout 6 should be used to show the mechanisms of upwellings in the sea. The teacher should take the opportunity to revise the Coriolis effect and surface currents (overhead/handout 2), which are involved in upwellings.

ACTIVITIES/ASSESSMENT

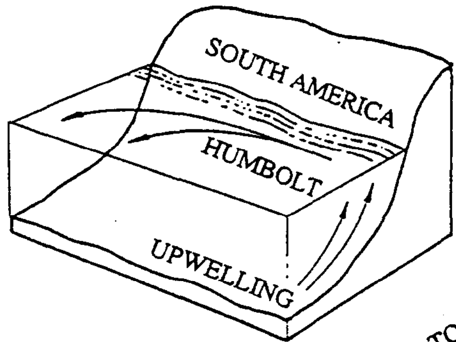
Students should be asked to describe the conditions which may result in upwellings.

OVERHEAD/HANDOUT 6
UPWELLINGS and OCEANIC FISHERIES

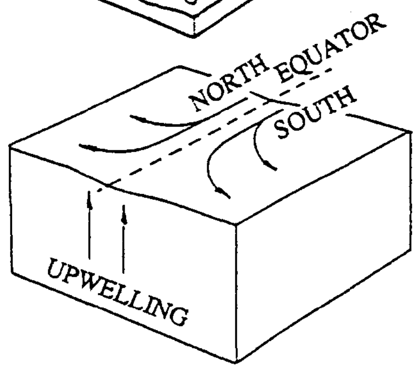
Wind blowing off the shore forces surface water away from the coast. This water is then replaced by deep water moving up the continental slope.

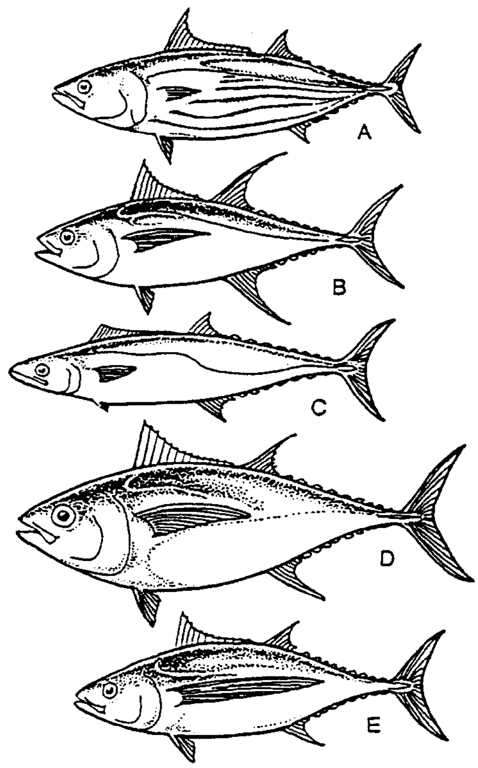


Off the west coast of South America, Coriolis forces acting on a northerly Humbolt current, force water away to the left. Shore-line surface waters are replaced by an upwelling of deeper water.



In the western Pacific two large currents (the north and south equatorial currents) move apart. This allows deeper water to move up to replace surface waters in the region of the equator.





Catches of tuna and related species (percentage of the total world catch).

A) skipjack tuna,
Katsuwonus pelamis (31%)

B) yellowfin tuna,
Thunnus albacares (24%)

C) Spanish mackerels,
Scomberomorus (9%)

D) big-eye tuna,
Thunnus obesus (6%)

E) albacore,
Thunnus alalunga (5%)

7. LAW OF THE SEA

BACKGROUND

Under European law, coastal countries have had jurisdiction over a narrow band adjacent to their coastlines since the 17th century. The width of this band was set at three nautical miles, the range over which a cannon could be successfully used! The ownership of the open sea, however, continued to be in dispute until the late 1950s, when a series of United Nations conferences produced the Law of the Sea Treaty. The treaty allowed countries to take control of offshore areas up to 200 nautical miles from their coastlines or outer reefs. Within this area of open sea, known as the Exclusive Economic Zone (EEZ), a country has the right to control economic activity which includes exploiting and managing fisheries resources. Under the Treaty, many coastal countries gained control over large areas of ocean. Even in the largest of the world's oceans, the Pacific, most of the open sea is controlled by individual countries (overhead/handout 7).

The declaration of EEZs have resulted in a fairer distribution of economic power. The developed nations, no longer assured of a cheap source of fish from the seas of other countries, must now negotiate with the owners of the resources, often poorer countries. Many coastal countries allow foreign nations, including Japan, USA, USSR, Korea and Taiwan, to fish for open water species such as tuna in their EEZs under either joint ventures or bilateral (or multilateral) agreements.

Joint ventures are partnerships between foreign and local fishers, and provide foreign investment and expertise, as well as a progressively increasing involvement of the local partners. Bilateral and multilateral agreements require foreign fishers to pay a fee for access to fish stocks not fully utilised by national fishers. By allowing foreign vessels into their EEZs for access fees, small nations can avoid the foreign debt involved in building their own fishing fleets. The choice between the two types of arrangement involves comparing the short-term gains from access fees under bilateral agreements with the possible long-term gains from increasing local involvement under joint ventures. Whichever country harvests the resource, the responsibility for resource management rests with the country controlling the EEZ. It is in that country's interest, and not necessarily in the foreign fishing country's interest, to ensure that catches taken are sustainable (see overhead/handout 42-44; Fisheries Management).

OBJECTIVES

The student will a) learn about the EEZs of countries, and b) understand the different types of access agreements with foreign fishing countries.

METHODS

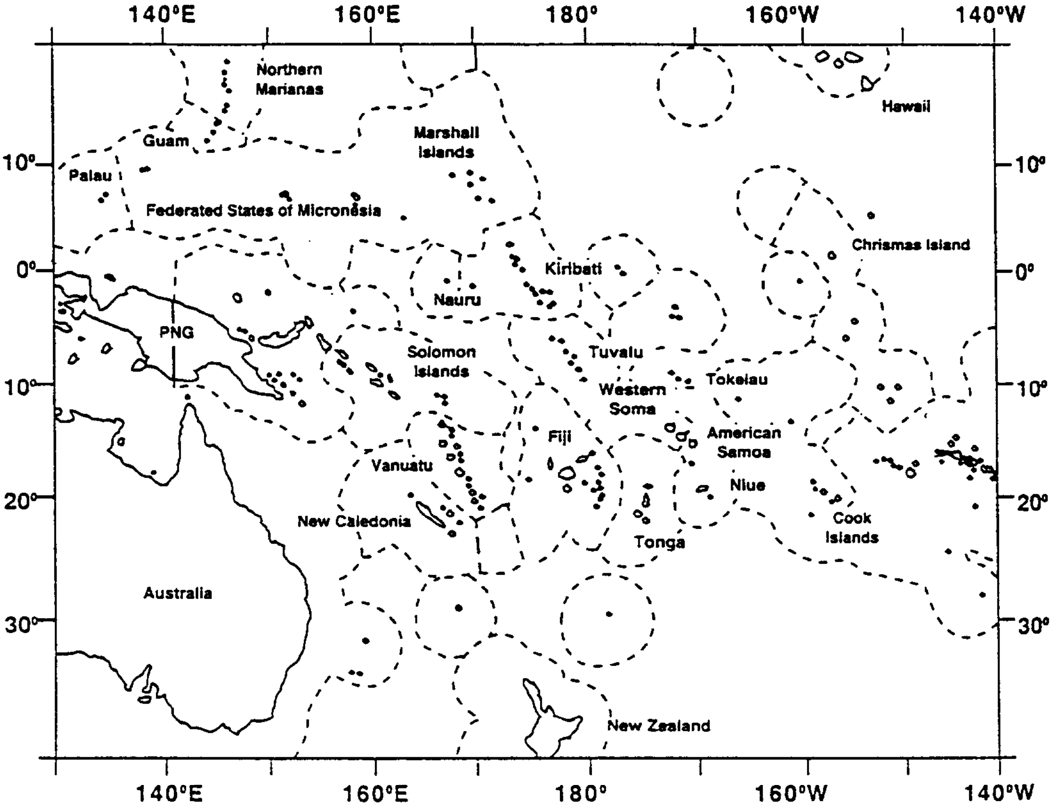
Overhead/handout 7 should be used to show the EEZs in the Pacific (as an example) and types of fishing access agreements.

ACTIVITIES/ASSESSMENT

Students should be asked to draw a chart showing the EEZs of their own and adjacent countries; areas of sea which are in dispute should be noted, as should the types of resources which are, or may be, important; consultation of marine charts and government documents may be necessary.

OVERHEAD/HANDOUT 7
LAW OF THE SEA

The Exclusive Economic Zones of Pacific Island countries.



Types of agreements between coastal countries and foreign nations

JOINT VENTURES

Joint ventures are partnerships between foreign and local fishers; these provide foreign investment and expertise and allow for a progressively increasing involvement of the local partners.

BILATERAL & MULTILATERAL AGREEMENTS

Bilateral and multilateral agreements require foreign fishers to pay a fee for access to fish stocks not fully utilised by national fishers.

8. OCEANIC POLLUTION: GLOBAL WARMING

BACKGROUND

The oceans, because of their huge size, have been regarded as convenient areas for the dumping of toxic wastes produced in industrially developed countries. The toxic material which attracts the most publicity in this regard is nuclear waste. Several countries use nuclear reactors to generate electricity, and have problems with the disposal of radioactive waste material. This waste has the potential to produce invisible radiation which can genetically alter, and even kill, living things. It is a tempting solution for countries to get rid of such dangerous waste by dumping it far out to sea. Although it is generally hard to control dumping outside territorial waters, small countries, such as those in the Pacific, have had some success in negotiating international treaties to prevent the dumping of industrial wastes.

An example of atmospheric pollution which indirectly affects the oceans, in particular sea-levels, is the "greenhouse-effect". A greenhouse is a small house made of glass which traps heat from the sun, and is used in cold climates to grow warm-climate plants. High levels of some gases, mainly carbon dioxide, in the earth's atmosphere may act in the same way as the glass in a greenhouse. Heat from the sun reaches the earth's surface but is prevented from escaping by a blanket of carbon dioxide; the greater the amount of this gas in the air, the greater is the proportion of heat trapped. Levels of carbon dioxide in the atmosphere, from burning forests and grassland and particularly fossil fuels such as coal and oil, have been increasing steadily over past years.

If the world's temperature is raised by the greenhouse-effect, the volume of seawater in the seas would expand and melting ice in Antarctica would add to the volume. An average increase in world temperatures by 1.5°C to 4.5°C over the next 50 years, could cause a rise in sea levels by from 20 to 140 cm. As a result, many low-lying coastal areas would be flooded. Further, the rise in water could be too rapid to allow the growth of coral to maintain reefs at sea-level, and many low coral islands and atolls could be covered by the seas (see overhead/handout 13 on the formation of coral reefs).

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

OBJECTIVES

The student will be able to understand the mechanisms causing global warming.

METHODS

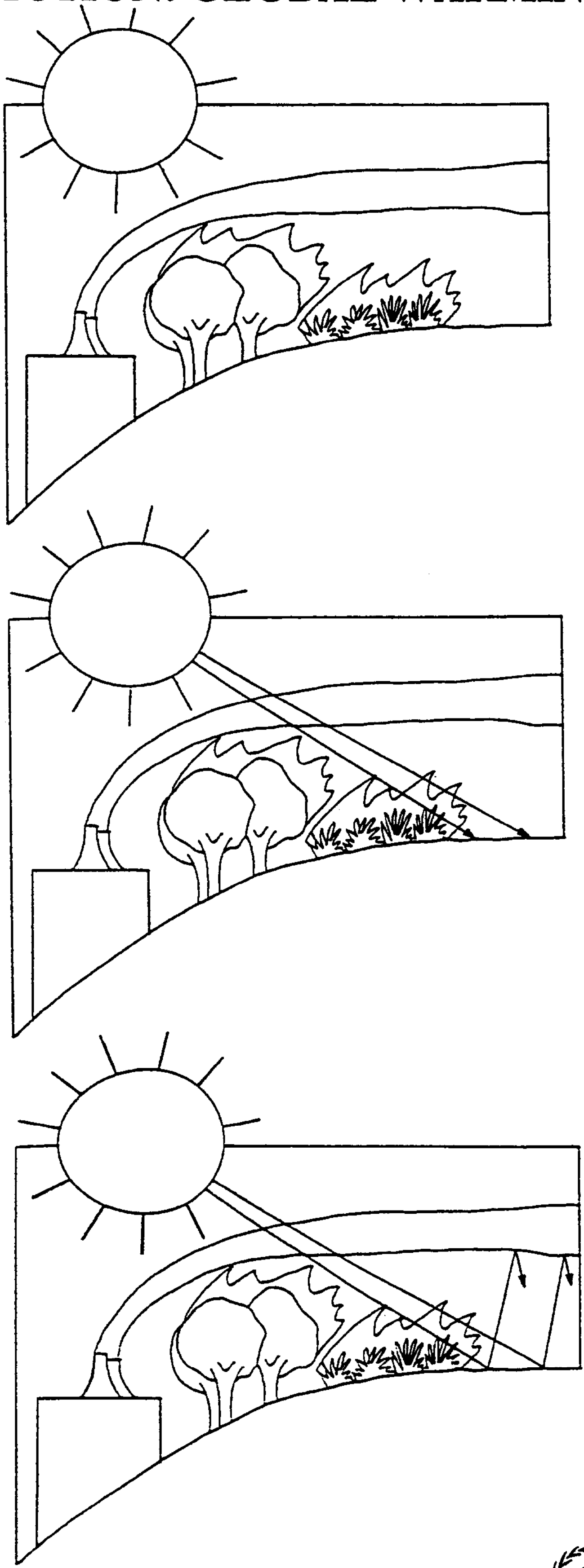
Overhead/handout 8 should be used to show the mechanisms causing global warming. Teachers should stress the activities of people which contribute to the problem.

ACTIVITIES/ASSESSMENT

Students should be encouraged to discuss the causes of global warming and to debate on actions which could taken to reduce the effect. Discussion of possible rises in sea levels should be related to local coast-lines and the growth of coral reefs.

OVERHEAD/HANDOUT 8

OCEANIC POLLUTION: GLOBAL WARMING



Burning forests, grassland and particularly fossil fuels.

↓

Levels of carbon dioxide in the atmosphere increase.

↓

Heat from the sun reaches the earth's surface.

↓

The blanket of carbon dioxide prevents heat from escaping.

↓

The earth gradually warms and the seas expand.

UNESCO-UNEP International Environmental Education Programme (IEEP)
The Oceans and Coastal Areas and their Resources. M.King and S.King.

COASTAL ECOSYSTEMS

The shore is a constantly changing environment, alternately covered and uncovered by tidal seas, and thus exposed to wave action and fluctuating temperature and variable salinity. In some areas, the coast is being eroded away by physical, chemical and biological activities and, in others, the shore is extending by the addition of particles ground from rocks and coral reefs, or silt deposited by rivers. These processes are natural, and problems occur most often where they are altered by the activities of people.

There are many different types of environments associated with coastal regions. Some coasts have beaches derived from rocks or coral, others have expanses of silt or mud deposited by rivers. Some tropical coasts have coral reefs fringing the shore, others have a sheltered lagoon between the shore and a barrier reef. In sheltered areas, there are often beds of seagrass and, near rivers or freshwater runoff, forests of specialised trees called mangroves. Although ecosystems are described under separate headings in this section, they are not independent of each other. They are interrelated, and things that affect one ecosystem may affect other types of ecosystems, even those some distance away.

9. TYPES OF COASTAL ECOSYSTEMS

BACKGROUND

Marine animals are specially adapted to living in particular environments. A range of different environments, and some of the species present in each, are shown distributed along a profile of a tropical coastline in overhead/handout 9.

Different ecosystems have different carrying capacities in terms of marine life, and this is most closely related to the ecosystem's available nutrients and primary productivity (the production of organic material by plants). Sheltered estuaries often contain high nutrient loads derived from associated rivers and run-off from the land. These areas support many marine and shore-line plants, high primary productivity, and a high abundance and large diversity of marine animals. Surf beaches on the other hand, with their low nutrient loads and drifting sand, are difficult place for plants and animals to become established. An indication of the productivity of different ecosystems is suggested by the mean yield per unit area of marine species given in the table on overhead/handout 9.

OBJECTIVES

The student will be able to appreciate the variety of ecosystems in coastal areas.

METHODS

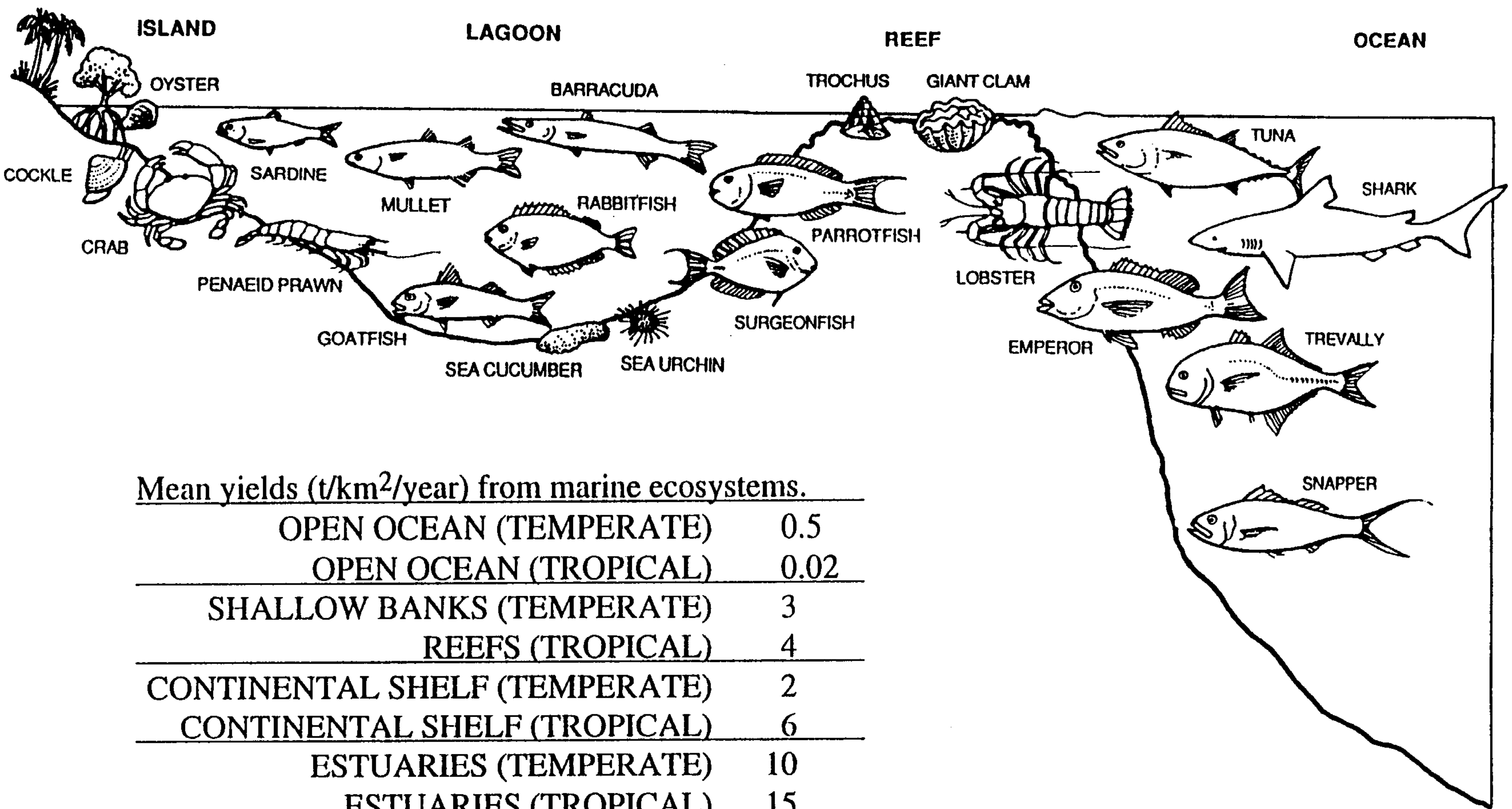
Overhead/handout 9 should be used to show the range of environments, and distribution of types of marine animals, along a depth profile off a tropical coast.

ACTIVITIES/ASSESSMENT

A field trip may be arranged for students to view a range of local environments, such as sheltered bays, surf beaches, coral reefs, and mangrove areas; written reports could itemise and discuss the different types of local marine environments.

TYPES OF COASTAL ECOSYSTEMS

The distribution of fish and other marine species along a profile of a tropical coastal ecosystems is shown below.



Mean yields ($t/km^2/year$) from marine ecosystems.

OPEN OCEAN (TEMPERATE)	0.5
OPEN OCEAN (TROPICAL)	0.02
SHALLOW BANKS (TEMPERATE)	3
REEFS (TROPICAL)	4
CONTINENTAL SHELF (TEMPERATE)	2
CONTINENTAL SHELF (TROPICAL)	6
ESTUARIES (TEMPERATE)	10
ESTUARIES (TROPICAL)	15
UPWELLINGS	18

10. BEACHES and SEAGRASS

BACKGROUND

Beaches are formed by particles of material washed ashore by waves and currents, or, in some cases, particles carried from inland by rivers. In tropical regions, most beaches consist of coral which has been broken up into particles by storms, or has passed through the guts of coral-eating fish such as parrotfish. In each case, the coral skeletons are broken down to small particles which can be carried by 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 on low-lying areas such as coral atolls, where they protect land which is often only a few metres above sea-level.

The waves which carry coral sand inshore may reach the shore-line at an angle. In this case, sand is not only carried inshore but along the shore in what is called a longshore drift. If the longshore drift is interfered with, say by the construction of a breakwater, the beach will be affected as shown in overhead/handout 10.

In some shallow sandy areas there may be extensive underwater meadows of seagrass, which provides shelter and food for many different marine animals. Seagrasses are similar to flowering plants on land. Unlike marine algae, they have root systems to gain a foothold in drifting sand which is subsequently stabilised. Seagrass also traps more sand which builds up to form sand bars and sandflats, and eventually decay to form a material called detritus, which is used as a source of food by many marine species.

In many coastal areas, sand is taken from beaches or dredged from seagrass beds in coastal waters for making concrete for the construction of buildings. This has to be undertaken very carefully, preferably in areas where there will be minimal impact on the coastal environment.

OBJECTIVES

The student will be able to understand a) how beaches are formed, b) the effect of longshore currents, and c) the importance of sandy beaches and seagrass in the coastal environment.

METHODS

Overhead/handout 10 should be used to show how beaches are formed, longshore currents, and the importance of seagrass in marine ecosystems.

ACTIVITIES/ASSESSMENT

Sample topics for discussion could include;

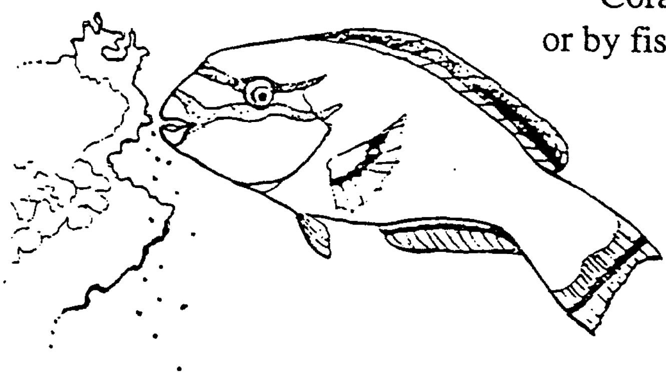
a) The formation of beaches on tropical coasts, including the role of coral-eating fish.

b) How longshore currents affect the movement of sand along local shorelines; students should examine local beaches for indications of the direction of any longshore drift.

c) The roles of seagrass in marine ecosytems.

OVERHEAD/HANDOUT 10
BEACHES & SEAGRASS

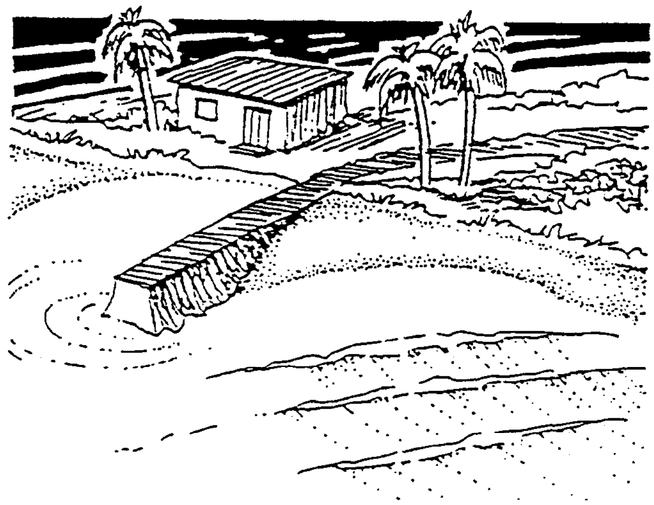
In tropical areas, most beaches are formed from particles of coral.



Coral is broken up by storms or by fish such as the parrot fish; which eats coral polyps. The remains of the coral skeletons pass through its gut as fine sand.

The sand is then carried by waves and deposited inshore where beaches are formed. Sand may also be carried along a shore in a longshore drift.

In the figure, the longshore drift is from right to left. The breakwater causes the beach to build up on the right and to gradually disappear on the left.

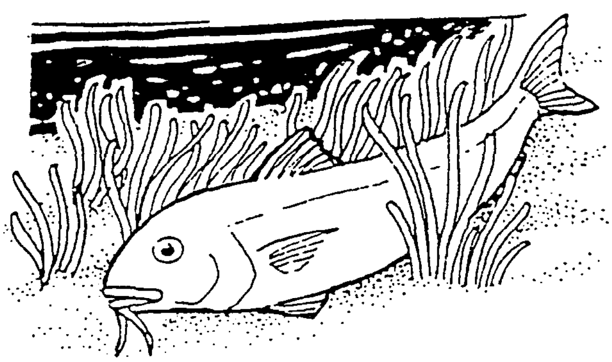


Beds of seagrass,

a) contribute food to shallow-water ecosytems,

b) provide shelter for marine species, and,

c) stabilise foreshores.



11. MANGROVES

BACKGROUND

The word "mangrove" is used to refer to over 90 different types, or species, of trees, many of which are unrelated to each other. These trees vary in size and appearance but are alike in that they are specialised for life at the sea's edge. Three different species of mangroves are shown in overhead/handout 11.

Mangroves grow in sheltered areas of brackish water, where freshwater mixes with seawater, half-way between the land and the sea. Thus their roots grow in an alternating environment of sea water and freshwater runoff from the land.

Mangroves play an important role in providing shelter for marine creatures and in producing large amounts of organic matter which is used as food. Through their root systems, mangroves take up nutrients which are often found dissolved in water running off the land. Like other plants, mangroves convert the nutrients to plant material by using sunlight in a process called photosynthesis. Parts of the mangrove, such as fallen leaves, rot away to form the decomposed material called detritus. Over one tonne of mangrove leaves may be produced each year by one hectare of mangrove trees. The decaying leaves and detritus form a constant supply of food for crabs, shrimps and some fish. The young, or juveniles, of some species such as shrimps use mangroves as areas in which to grow (nursery areas) before moving out to deeper water. Other species come into mangrove areas to breed, and many large fish live in or visit the mangroves to feed on smaller creatures.

Mangroves are also important in protecting and building up shore-lines. The trees have an underground network of roots which hold the earth together and prevent it being washed away. The roots act like a comb, trapping particles and sediments which gradually build up and extend shore-lines. The mangrove front advances towards the sea and the newly-formed land behind the front fills up with other tropical plants.

To summarise, many marine species use the mangroves for at least part of their life-cycle. Mangroves provide;
a) Permanent homes for species such as oysters and crabs.
b) Nursery areas, or areas where the young grow up before moving out to deeper water, for animals such as shrimps (see the shrimp life-cycle on overhead/handout 32).
c) Breeding areas for fish such as the garfish.
d) Feeding areas for larger fish such as snappers which visit the mangroves to feed on smaller fish and other creatures.

Unfortunately, many mangrove areas throughout the world have been destroyed. Mangroves usually grow in flat muddy, insect-ridden areas, which very few people regard as worthy of saving. As a result, mangrove areas are often used as rubbish dumps or the trees are cut down and the land filled in for housing or other development. This destruction is usually called "reclamation" (the claiming back of "useless" wasteland) by those developers who wish to disguise such destructive practices. Both public and government attitudes need to change so that mangroves areas are regarded as vital parts of the coastal environment. One way of protecting mangroves from destruction is to designate mangrove areas as marine reserves - areas in which trees cannot be cut down.

Mangroves are also under threat from the less direct activities of people - activities which alter the environment in which mangroves live. The mangroves shown in overhead/handout 11 have been killed by the construction of a coastal road. The road has cut off the flow of fresh water runoff from the land. The water to the left of the road has become too salty and the water to the right of the road has become too fresh. The mangroves could have been saved by building the road inland behind the mangroves - or perhaps by burying pipes under the road to allow the passage of tidal seawater and freshwater runoff.

Mangroves are particularly affected by;

a) Changes in the tidal flow or salinity (salt content) of the surrounding water,
b) Construction work or coastal development which cause sediments to build up, or to be washed away from mangrove root systems, and
c) Pollution such as chemicals, oil or excessive amounts of sewage in the water.

OBJECTIVES

The student will be able to a) appreciate the importance of mangrove areas, and the role they play in marine ecosystems, and b) discuss the value of mangroves, and investigate the ways in which they are being destroyed.

METHODS

Overhead/handout 11 should be used to show the common types of mangroves. The teacher should discuss the importance of mangroves to marine life, and the ways in which mangroves are being destroyed. The importance of mangrove ecosystems in the life histories of many marine species should be emphasised.

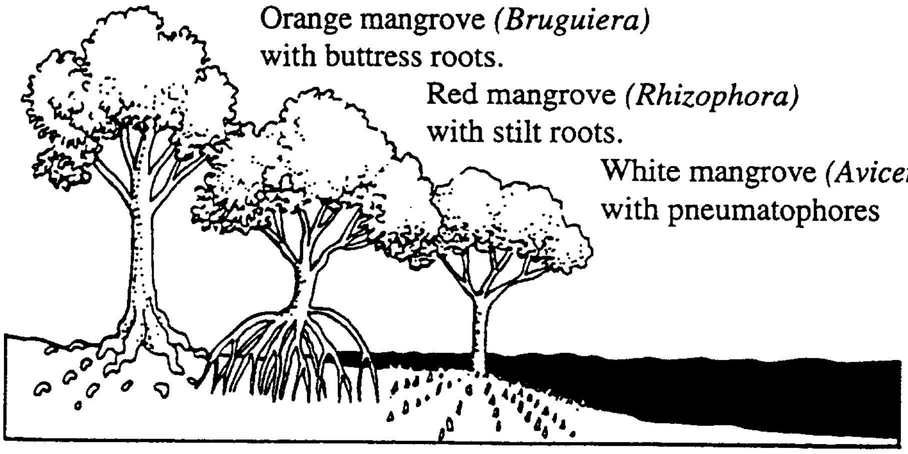
ACTIVITIES/ASSESSMENT

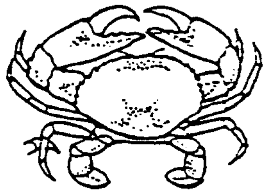
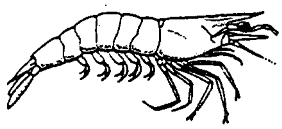
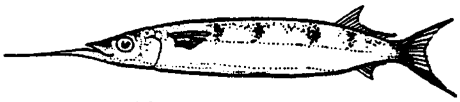
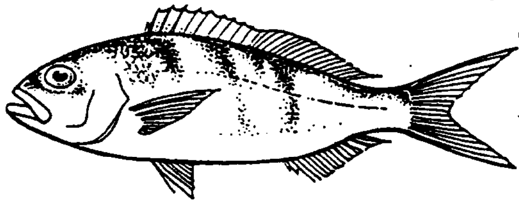
A field excursion to a local mangrove area may be possible. Students should be asked to visually assess the stands of mangroves, suggest how they are being affected, and discuss how the situation may be improved.

Students may take part in a field project to examine the distribution of marine life across mangrove mud flats. Use overhead/handout 14 to brief students. Students doing subjects involving statistics can take this exercise further, by estimating the abundance of marine animals by depth.

OVERHEAD/HANDOUT 11

MANGROVES



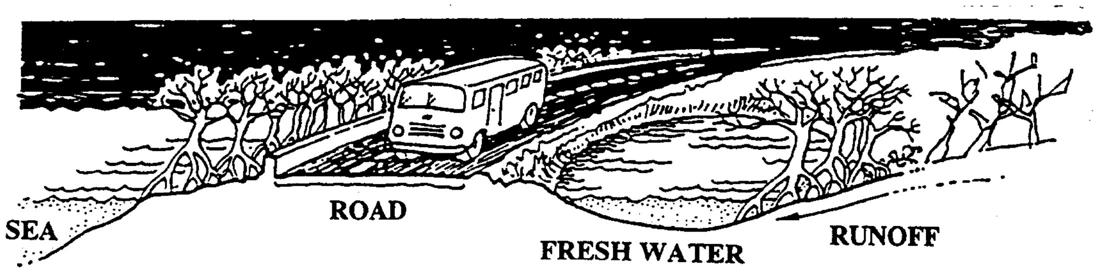
Mangroves provide;

a) Permanent homes for species such as oysters and mud crabs.

b) Nursery areas for animals such as shrimps.

c) Breeding areas for some fish like the garfish.

d) Feeding areas for larger fish, such as the snapper, which visits mangrove areas to feed.



Mangroves killed by the construction of a coastal road which has formed a barrier between the flow of tidal seawater and fresh water.

Mangroves are particularly affected by...

- changes in the tidal flow or salinity of seawater,
- the build up of sediments around the mangrove's roots, and
- pollution such as by chemicals, oil or sewage in the water.

12-13. CORALS and CORAL REEFS

BACKGROUND

There are hundreds of different types of coral. All corals however, are made up of small animals called polyps. Most coral polyps are less than 1 cm in diameter and live side by side in groups or colonies. A few species, such as the mushroom coral, have solitary polyps up to 20 cm in diameter.

Coral polyps are simple marine animals related to jellyfish and sea anemones. The small arms or tentacles of the coral polyp (lower figure in overhead/handout 12) are used for capturing food drifting in the water currents. Corals can also obtain food from small plant cells (called zooxanthellae) which live inside their tissues. The small plant cells use sunlight, and nutrients in the sea water, to produce food which is shared with the coral. The coral provide shelter and protection for the small plant cells. This is an example of symbiosis - a relationship between two different organisms which live together for the benefit of both organisms. Because of their reliance on zooxanthellae, most corals, like plants, require sunlight for photosynthesis and can only live in clear, shallow, brightly lit waters.

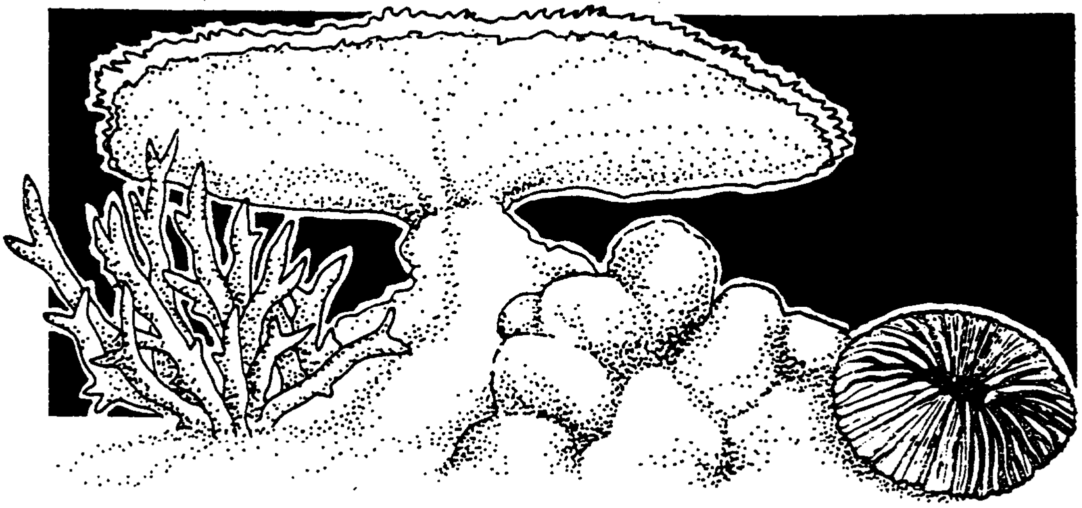
Coral polyps produce eggs which are fertilised by sperm and hatch into very small floating larvae. Of many million larvae drifting in the surface layers of the sea, a few manage to reach shallow water and settle on suitable hard surfaces to grow into new polyps. Eventually a large number of polyps build a shared skeleton which has the shape of a particular kind of coral. Coral colonies grow in a variety of shapes and sizes and their common names often reflect their appearance (see upper figure in overhead/handout 12).

Many massive coral colonies are known as "reef builders", and collectively form the large masses of coral rock called a coral reef. When polyps die, rock-like skeletons of calcium carbonate or limestone are left. New polyps grow on top of the remaining skeletons. Coral reefs, therefore consist of the skeletons of many thousands of dead polyps - one kg of coral rock may contain over 80 000 polyp skeletons. Living polyps are only on the thin outer layer of a coral reef which continue to grow outwards and upwards with each generation. Although it takes many years, some of the world's smallest creatures, coral polyps, are responsible for building some of the world's largest natural structures, coral reefs, which may be many kilometres long.

A coral reef is part of a complex ecosystem which includes many animals and plants. It provides food and shelter for a greater variety of living things than most other natural areas in the world. Many coral-reef animals, such as clams, crabs, lobsters and fish, are important food items for people living in tropical coastal areas.

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 gradual sinking of an oceanic island over many thousands of years. As long as a newly-formed island in tropical waters is within reach of drifting coral larvae, it would soon acquire a fringing reef of coral. As the island slowly subsides or sinks, the reef front of 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. This sequence in reef formation is illustrated on overhead/handout 13.

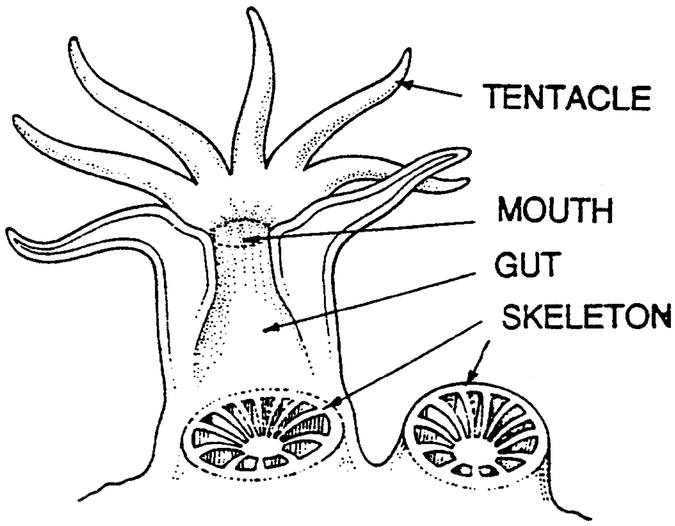
OVERHEAD/HANDOUT 12
CORALS AND CORAL REEFS



Some common types of hard, reef building, corals including (from left) staghorn coral, table coral, boulder coral *(Acropora* species), and a solitary polyp of a mushroom coral *(Fungia).*

A coral polyp
cut away to show the
gut and the skeleton
beneath the polyp.

A skeleton without
its polyp is shown
on the far right.



Coral reefs are a vital part of the coastal environment in the tropics. The skeletons of corals break down to rubble and eventually to sand which helps build up shore-lines and beaches. Coral reefs also protect coastlines and coastal villages from large ocean waves created by storms and cyclones.

Barrier reefs form sheltered lagoons where more delicate plants and animals can live and where people can safely fish. Coral reefs create places where animals such as crabs, lobsters, clams and reef fish can live, and are important food sources for nearby villages. Without coral reefs, many coastal areas would be without protection from the sea, and without such a large variety of seafood.

Although corals have some natural enemies, such as the parrot fish (see overhead/handout 10) and the crown-of-thorns sea star (see overhead/handout 26), the activities of people present the greatest threat to coral reefs. Corals are collected for use as building blocks or for sale as souvenirs to tourists. In some areas, corals are being destroyed by destructive fishing methods, such as the use of explosives and poisons - these methods kill not only fish but also coral polyps. Other activities, such as dredging harbours, coastal building projects and forestry may release silt into the water which blocks off sunlight or smothers the coral polyps. Once destroyed corals may take a long time to grow back.

OBJECTIVES

The student will be able to a) appreciate the importance of coral and coral reefs, b) name the different types of coral reef, and ways in which they are formed, and c) discuss the ways in which corals and coral reefs are being damaged.

METHODS

Overhead/handout 12 should be used to show the structure of a coral polyp and to discuss the formation of coral colonies. Overhead/handout 13 should be used to show how different types of coral reefs are formed, and the ways in which corals are being destroyed, particularly by human activity.

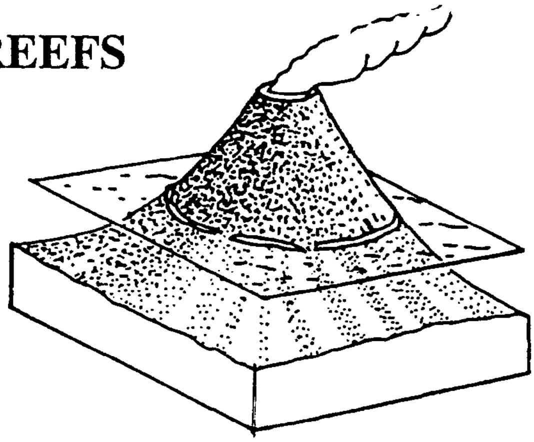
ACTIVITIES/ASSESSMENT

A field excursion to a local coral reef area should be undertaken if possible. Students should be asked to visually assess the reefs, and suggest how they are being affected by human activity.

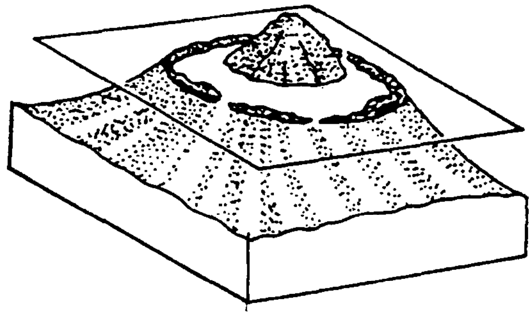
Students may take part in a field project to examine the distribution of marine life across a coral reef from the inner or shore edge to the outer reef edge. Use overhead/handout 14 to brief students. Students doing subjects involving statistics can take this exercise further, by estimating the abundance of marine animals along a transect from the inner edge of the reef. The abundance of species will depend on physical factors such as wave action and oxygenation

OVERHEAD/HANDOUT 13

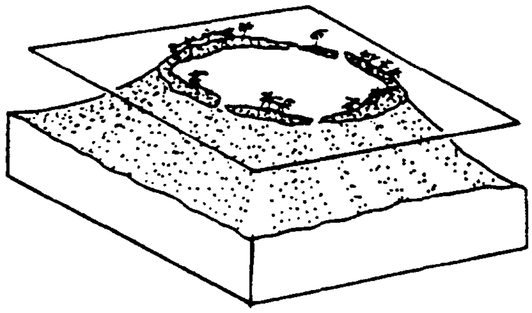
CORALS and CORAL REEFS



FRINGING REEFS grow at the edges of continents and islands. The reef front contains actively growing corals, and pieces of broken coral are washed up as rubble on the reef flat.



BARRIER REEFS are separated from the shore line by a lagoon which is often deep. Corals grow in the calm waters of the lagoon as well as on the reef front.



ATOLLS are coral reefs growing in the shape of a circle. The reef, which often has small islets on it, surrounds a lagoon.

People can damage coral reefs by.....

a) collecting coral as building blocks or as souvenirs for sale to tourists,

b) damaging live coral by anchoring or landing boats on the reef.

c) overfishing or taking too many animals of one type from the reef - this affects the delicate balance between living things on the reef,

d) using destructive methods of fishing, such as explosives and poisons.

e) pollution from factories and oil from ships in the water, and,

f) silt from dredging harbours, coastal building projects and forestry and agriculture.

OVERHEAD/HANDOUT 14
SURVEYING MARINE ECOSYSTEMS

OBJECTIVES: To discover the distribution of selected organisms (choose 3 to 6 different species) along the gradient of a particular ecosystem, and to learn about basic quantitative sampling.

METHODS

a) Lay a rope, marked at 5 m intervals, along the habitat under investigation; this forms a transect at right-angles to the shore.

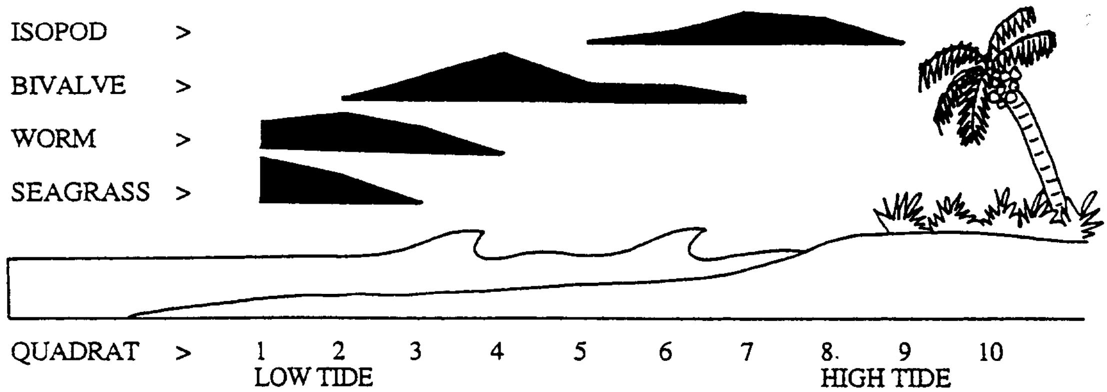
b) Starting from the seaward end of the rope at low tide, mark a square quadrat (say 1 m by 1 m) at each mark on the rope.

c) Collect all of the animals under investigation from each quadrat; in soft substrates, it will be necessary to dig down to a depth of 20 cm. Save the sample from each quadrat in a separate numbered bucket.

d) Record the numbers of each type of animal within each quadrat on a form like the one shown below.

SPECIES	Quadrat 1	Quadrat 2	Quadrat 3	Quadrat 4 etc	TOTAL

e) Construct a graph showing the distribution of marine animals along the transect, like the one shown below.



15-16. FOODWEBS, ENERGY PYRAMIDS and the WATER CYCLE

BACKGROUND

Within the various environments described in previous sections there is a flow of material and energy from one living organism to another. Energy from the sun and food material (mainly nitrates and phosphates) are used by plants to form plant material through the process of photosynthesis. The plant material is eaten by animals which are eaten by other, usually larger, animals.

This flow of energy and food material is sometimes called a food chain. For a terrestrial example, if people eat pigs which feed on coconuts, the food chain can be drawn as

COCONUTS ----> PIGS ----> PEOPLE.

However, food relationships, particularly in the tropics, are much more complex than this. There are often so many connecting lines between different plants and animals that the food chain is better described as a food web.

The food web shown in overhead/handout 15 shows a simplified, tropical, marine food web. Plants such as mangroves **(1)** and seagrass **(2)** use sunlight to produce plant material from carbon dioxide and mineral 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)**. A wide range of animals, including the sea cucumber **(6)**, feeds on detritus in the sand.

Microscopic plants, called phytoplankton (greatly magnified in **7**), drift near the surface of the sea, and are eaten by small floating animals called zooplankton (magnified in **8**). Some small plant cells, called zooxanthellae, live inside animals such as 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.

Carnivores are animals which eat other animals. Many smaller carnivores, such as sardines **(11)**, feed directly on the zooplankton. Corals also have the ability to feed on zooplankton, which they capture by using specialised stinging cells. Fish, such as emperors **(12)**, eat a wide range of smaller fish, and are themselves hunted by larger animals such as sharks **(13)**.

Each living thing is part of a food web in which material or energy accumulated at each step by plants or animals as biomass (weight of living material) is transferred as food to the next level. This is why reducing the numbers of one marine species, by overfishing or by destroying its habitat for example, may affect many other species. The flow of energy through food webs can also be illustrated by reference to an energy pyramid as shown in overhead/handout 16.

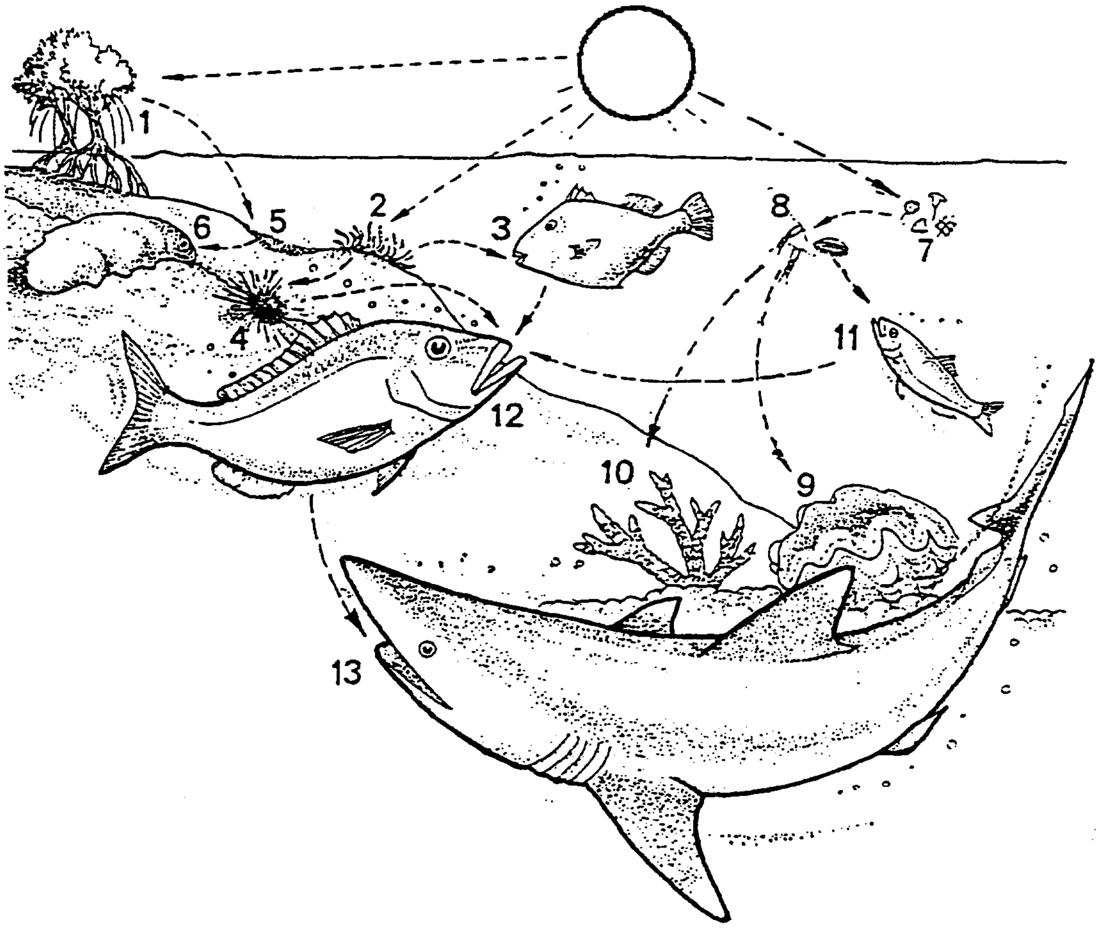
OVERHEAD/HANDOUT 15

FOODWEBS

The flow of energy and food material through an ecosystem is sometimes called a FOOD CHAIN and may be written most simply as;

PLANT MATERIAL > HERBIVORES > CARNIVORES

However, food relationships, particularly in the tropics, are much more complex than this, as shown in the tropical FOOD WEB below.



1.	mangroves	7.	phytoplankton (greatly magnified)
2.	seagrass	8.	zooplankton (magnified)
3.	triggerfish	9.	giant clam
4.	sea urchin	10.	coral
5.	detritus	11.	sardine
6.	sea cucumber	12.	emperor
		13.	shark

The first or lowest trophic level in the energy pyramid, the primary producer level, consists of marine plant material. This plant biomass is passed on to the next trophic level (the herbivore level) which contains the prey species for a wide range of carnivorous fish (the carnivore level). As some fish feed on other carnivores, there may be several trophic levels of carnivores.

The biomass values shown to the right of the energy pyramid arbitrarily assume a 10 per cent level of ecological efficiency (ie. the energy passed from one trophic level to the next). At each level most of the energy is lost. Animals use most of their food energy for bodily functions, and are able to convert only a fraction of the energy taken in to growth (which may be transmitted to a predator). There is, therefore, a decrease in total biomass at each succeeding trophic level. Thus animals at higher trophic levels are not able to maintain large populations - it takes about one tonne of plant material to produce one kilogram of a carnivorous fish such as a snapper or a barracuda!

Food webs requires a constant input of energy from the sun. This is not the case with materials such as carbon, nitrogen and water, which can be used over and over again. An example of this is the water cycle.

Water enters the atmosphere by constant evaporation from rivers, oceans, land and the bodies of plants and animals. Water loss from plants is usually through the leaves in a process called transpiration. The water vapour in the atmosphere collects as clouds and falls back to earth as rain. When rainwater falls on the land, some is used by plants and animals, and some forms rivers or percolates down through the soil into the water table below. The water in rivers and water tables eventually finds its way back to the sea.

OBJECTIVES

The student will be able to a) understand the flow of material through a food web, b) understand the concept of an energy pyramid, and the loss at each ecological level, and c) understand, and illustrate in diagrammatic form, the water cycle.

METHODS

Overhead/handout 15 should be used to show the flow of food material through an ecosystem. Overhead/handout 16 can be used to suggest the loss at each ecological level. The diagram of the water cycle on overhead/handout 16 should be used to discuss the pathways of water movement through ecosystems.

ACTIVITIES/ASSESSMENT

Topics for discussion could include;

a) The weight (biomass) of primary production (phytoplankton and other plants) required to produce one kilogram of top carnivore, such as a shark.

b) The types of marine animals collected or caught in large numbers along the local coastline, and how this activity might affect coastal foodwebs and ecosystems.

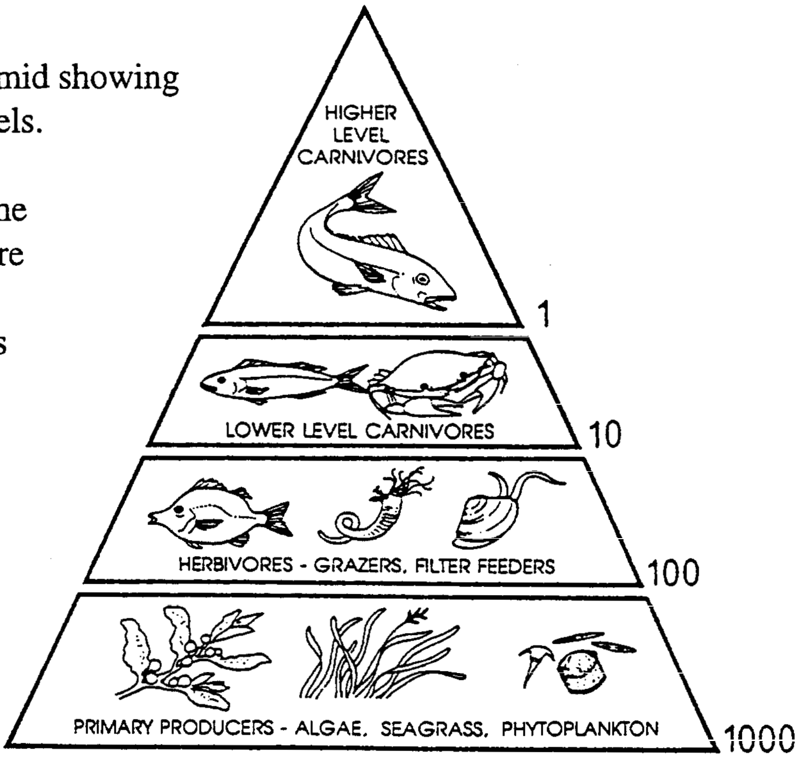
c) The necessity and mechanisms of recycling water in the ecosystem; this can be extended to include the cycling of carbon, nitrogen and phosphorus.

OVERHEAD/HANDOUT 16

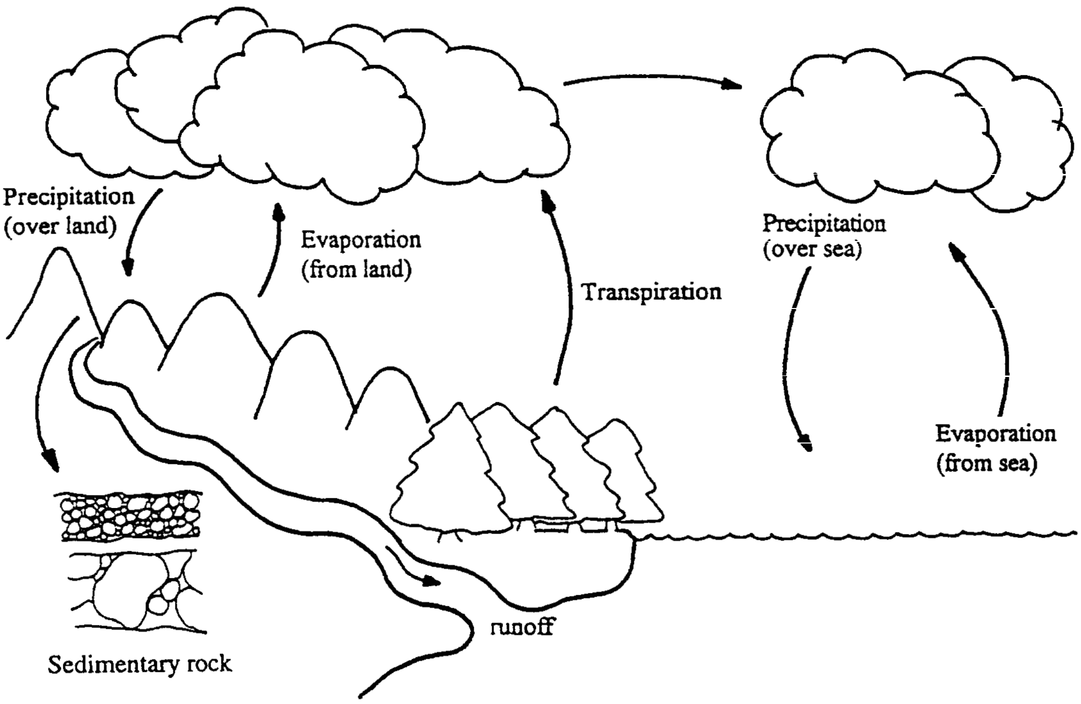
ENERGY PYRAMIDS and the WATER CYCLE

An energy pyramid showing four trophic levels.

The values on the right of the figure suggest the relative biomass present at each level.



THE WATER CYCLE - The pathways of water movement through ecosystems is shown below.



UNESCO-UNEP International Environmental Education Programme (IEEP)
The Oceans and Coastal Areas and their Resources. M.King and S.King.

17. BIOMAGNIFICATION; CIGUATERA

BACKGROUND

Although biomass decreases up the energy pyramid (that is from plants to high order carnivores), the concentration of any toxic material present may increase. That is, if toxic material in plants is eaten by herbivorous fish, the fish, and particularly their predators, may become even more toxic. This effect is called biomagnification. Some of the pollutants discussed in the next section act this way, and this is why larger carnivorous fish may be extremely toxic to human beings. In one meal a large carnivorous fish can gain the toxins accumulated by a smaller fish over its entire life-span. Outbreaks of the type of fish-poisoning known as ciguatera is an example of biomagnification, and may be associated with polluted water and coral damage. A microscopic plant (belonging to a phytoplankton group known as dinoflagellates) called *Gambierdiscus toxicus* is believed to be responsible for introducing toxic material into coral reef food chains. The sequence of events leading to an outbreak of ciguatera are shown in overhead/handout 17.

The dinoflagellate, *Gambierdiscus toxicus* occurs as a film on corals and seagrasses. It contains a chemical precursor, which is converted to ciguatoxin in the livers of herbivorous fish. Small fish feeding on *Gambierdiscus* become toxic, and the toxins are passed on and concentrated in the flesh of large predators such as moray eels, snappers and barracuda which eat the small fish. The dinoflagellates reach high abundance in seasons when the sea contains large quantities of nutrients, such as during the wet season, and after periods of disturbance such as those caused by cyclones and harbour dredging. During these periods, people eating these usually edible fish become affected by ciguatera, and suffer from tingling, numbness, and muscle pains. In severe cases, death may result. There is no reliable, cheap test to determine whether or not particular fish are ciguatoxic (although there is much unreliable folklore), and this causes marketing problems in many tropical coastal fisheries.

OBJECTIVES

The student will be able to understand the concept of biomagnification, using ciguatera, as an example.

METHODS

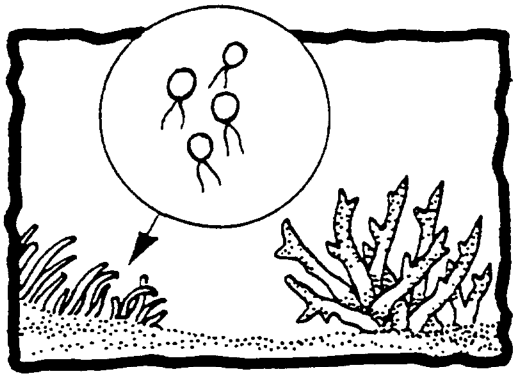
The teacher should explain the concepts of biomagnification using the energy pyramid on overhead/handout 16; although biomass decreases up the energy pyramid, the concentration of any toxic material present may increase. The fact that many pollutants act this way should be stressed. Overhead/handout 17 should be used to show the sequence of events leading to an outbreak of ciguatera.

ACTIVITIES/ASSESSMENT

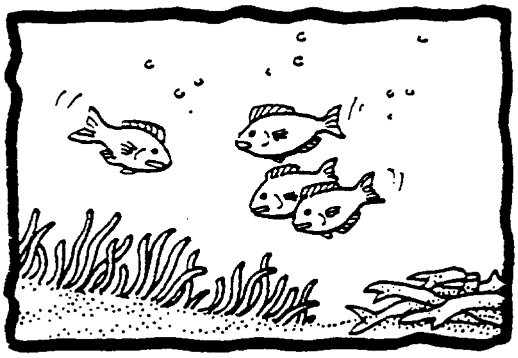
To appreciate how toxic materials may become concentrated in the food chain, students may complete the following calculations. A large carnivorous fish (weighing 5kg) eats three medium size fish (with a mean individual weight of 0.5 kg) in one day. The medium-size fish have each fed on six sardines (with a mean individual weight of 0.08 kg) in the same day. The flesh of the sardines contains 0.001 mg per kg of a toxin. Disregarding loss of toxic material due to metabolism or excretion, estimate the concentration of toxins in the large carnivorous fish.

OVERHEAD/HANDOUT 17
BIOMAGNIFICATION; CIGUATERA

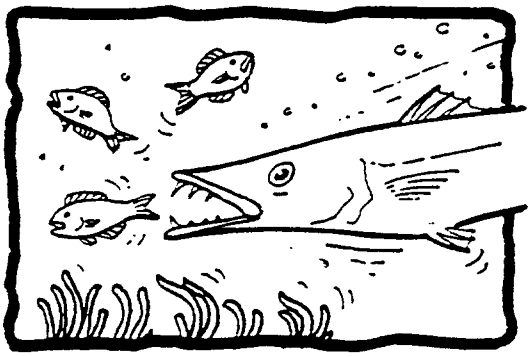
Microscopic cells of *Gambierdiscus toxicus* (shown enlarged in the circle) live in a thin film which covers the seagrass shown to the left of the coral.



If the coral is destroyed, nutrients are released, allowing *Gambierdiscus* to grow and increase in numbers. Small fish feeding on the *Gambierdiscus* become toxic.



The toxic substances are passed on and concentrated in the flesh of large predators such as moray eels and snappers, as well as the barracuda shown here.



People eating these usually edible fish become sick with ciguatera. They suffer from tingling, numbness and muscle pains, and, in some severe cases, may die.

18. RELATIONSHIPS BETWEEN ECOSYSTEMS

BACKGROUND

Although it is convenient to refer to different coastal ecosystems under separate headings as has been done in this book, it should be emphasised that they are actually interrelated. Coastal marine ecosystems are connected by currents and the tidal movements of sea-water. This water flow transports not only food material, but pollutants from one ecosystem to another. This has important implications in protecting the coastal environment. It means that any activity which damages one ecosystem may damage a different one in another, and sometimes distant, place. If a forestry operation causes erosion of the soil, rivers may carry silt over large areas of adjacent coastline, covering and killing seagrass and corals.

In many cases, ecosystems are physically dependent on the well-being of other systems. If a coral reef is destroyed, for example, increased wave action on the previously protected shoreline may erode beaches and mangrove areas. The inter-dependence of ecosystems suggests that management of the coastal environment has to be undertaken on a broad front, with the involvement of many different agencies (for example, those responsible for agriculture, forestry, fisheries, public works and water supply). This approach is termed Integrated Coastal Management (ICM).

Different types of ecosystems are also connected by the movement of fish and other species between them. Some young or juvenile fish grow up in an inshore nursery area, often seagrass or mangrove areas, until they reach a certain size. They then migrate out (or are recruited) to the offshore stocks of adult fish. After the adults reproduce, the fertilised eggs hatch into small larvae which eventually drift back to the inshore nursery areas. Inshore nursery areas provide the young of a species with a sheltered environment and, since these areas are usually highly productive, an abundant supply of food.

Inshore ecosystems are connected with those further offshore by the overlap in the distribution of predator and prey species, and the flow of material through food chains. The production of plant material is often greatest in nutrient-rich inshore areas. This material is consumed by herbivorous species, which, in turn, are consumed by species that range further offshore, and whose distribution overlaps that of its food species.

OBJECTIVES

The student will be able to a) appreciate that, although it is convenient to refer to different coastal ecosystems under separate headings, they are actually interrelated, and b) understand the mechanisms which connect coastal and related terrestrial ecosystems.

METHODS

The teacher should discuss the interrelation of ecosystems using overhead/handout 18.

ACTIVITIES/ASSESSMENT

Students should be asked to discuss the ways in which the different parts of the local coastal environment are interrelated. How are these relationships being affected by human activity. Which agencies could be involved in preparing a coastal management plan? - see Integrated Coastal Management.

OVERHEAD/HANDOUT 18
RELATIONSHIPS BETWEEN ECOSYSTEMS

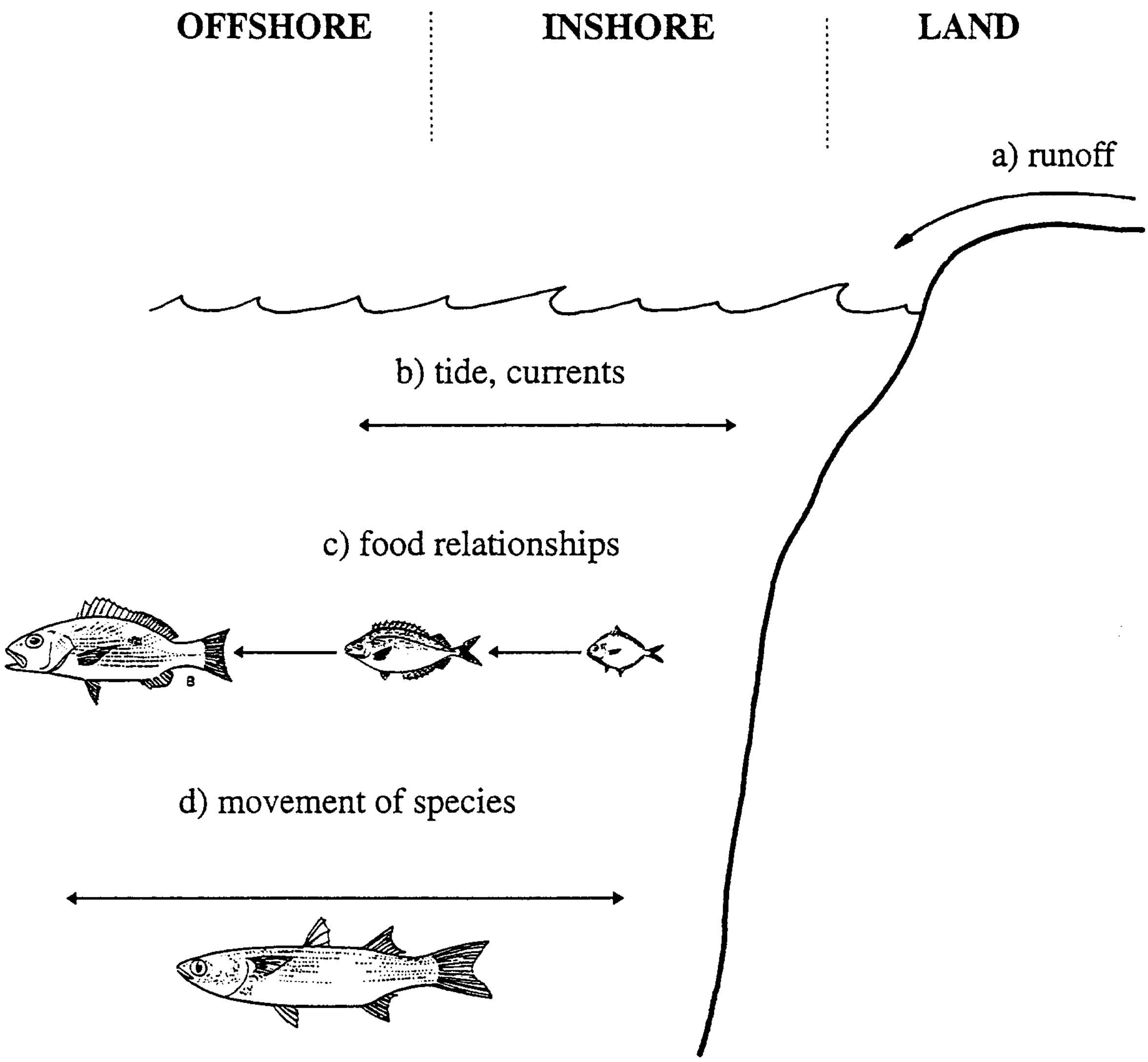
Different coastal ecosystems are connected by;

a) Runoff of rainwater from land, and the erosion of the coast by the sea.

b) Currents and the tidal movement of sea-water.

c) The transport of material through foodwebs.

d) The movement of marine species between ecosystems.



COASTAL DEVELOPMENT & SOURCES OF POLLUTION

Pollution, in the context of this book, refers to the introduction of toxic or harmful materials to the environment by the activities of people. This often has a negative affect, either directly or indirectly, on marine life. Indirect effects may be through the food webs and biomagnification, or because damage to one type of ecosystem often damages another.

It should be noted, however, that the well-being of marine species can also be affected by natural processes. An isolated pool in a mangrove forest, for example, may contain so much rotting organic material that the dissolved oxygen is used up by bacteria; the water becomes brown and fish may die. Fish of the open ocean, including tuna, may concentrate mercury (a toxic metal) to high levels in their flesh, even though mercury occurs naturally only in very small quantities in seawater.

Water can be polluted by the introduction of material which is not in itself toxic, but still damages the environment - for instance the addition of silt to a river or the sea may kill some plants and animals. Even relatively inert material, such as plastic packaging material, besides producing visual pollution on coastlines, may have the effect of tangling and choking some marine creatures.

Pollution occurs at varying levels. Small amount of some pollutants in seawater may only be measured and their effects confirmed by close scientific examination. Other more toxic, or more concentrated pollutants, may devastate the environment causing the death of marine species and even people eating them.

19. SOURCES OF COASTAL POLLUTION

BACKGROUND

Some of the important pollutants and their sources are summarised in the drawing on overhead/handout 19, and are discussed in the following pages.

OBJECTIVES

The student will become familiar with the sources of pollution in the marine environment.

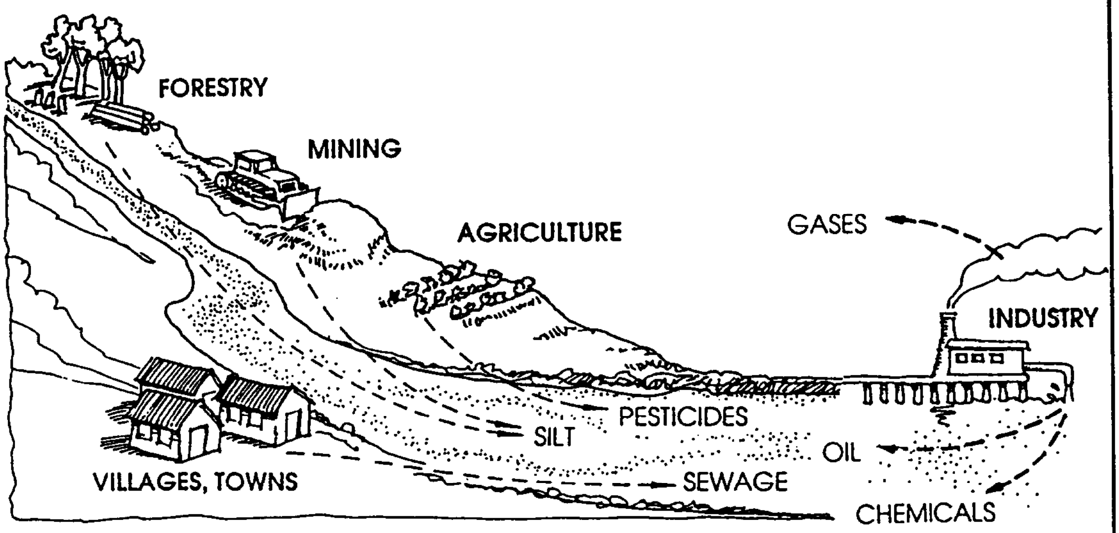
METHODS

Overhead/handout 19 should be used to show the range of pollutants and their sources. The overlapping of these sources of pollution and the interrelationships between ecosystems should be re-emphasised.

ACTIVITIES/ASSESSMENT

Students should list the activities which badly affect the local coastal environment, and investigate how the effects of these activities could be lessened. Students could consider the agencies which should be, or are, involved in preparing a coastal management plan - see Integrated Coastal Management.

OVERHEAD/HANDOUT 19
SOURCES OF COASTAL POLLUTION



SEWAGE: Sewage adds nutrients which encourage the growth of bacteria in sea water. The bacteria may use up so much dissolved oxygen that marine life suffocates. Sewage may carry pollutants such as detergents.

OIL: Although less toxic, oil can be a serious pollutant released by certain shore installations and by ships. Oil forms a thin film on the surface of the water which may cover and kill coral and other intertidal animals.

PESTICIDES & HEAVY METALS: Many of these are highly toxic, and their effects may be magnified through the food chain.

SILT: The major effect of silt is that it reduces the amount of sunlight penetrating the water, and therefore kills plants and some animals which require sunlight for survival. Silt may also damage the delicate gills of fish.

DISCARDED CONSUMER GOODS: Even relatively inert material, such as plastic packaging material, besides producing visual pollution on coastlines, may have an effect on marine life. Plastic bags may be mistaken for food by turtles, and discarded fishing gear continues to entangle fish.

20. VILLAGES, TOWNS and RESORTS

BACKGROUND

All development in coastal regions will affect the environment to some degree. In an attempt to gain more valuable waterfront land, mangrove areas may be "reclaimed" by cutting down the trees and filling in the land for housing. The construction of wharfs and breakwaters will interfere with water currents, the formation of beaches and the natural movements of fish.

The most common type of pollution in areas of high population is caused by sewage, human faeces and urine, in water which is released into the sea. Sewage may be treated, but this is expensive and requires areas of land for the construction of ponds as shown in overhead/handout 20. If sewage is held in large ponds much organic material will settle out as a sediment, and suspended particles may be removed by passing the liquid through gravel filter beds.

Whether treated or untreated, sewage released into the sea will tend to increase the quantity of nutrients, particularly nitrates (NO_3) and phosphates (PO_4), in the surrounding water. This will encourage the growth of bacteria which uses much of the dissolved oxygen. The degree of pollution may be measured by the consumption of oxygen or the biological oxygen demand (BOD) - the higher the BOD, the more polluted the water. High nutrient levels encourage the growth of marine plants and "blooms" of phytoplankton which turn the polluted water green, and eventually decompose, using up even more oxygen. In some cases, the growth of poisonous plant material such as the species which causes ciguatera may be encouraged (overhead/handout 17).

The composite graph in overhead/handout 20 shows what is likely to happen at various distances from a sewage outlet pipe. Close to the outlet there is a large amount of bacteria and the oxygen is used up (the water has a high BOD). Very few marine animals can live in such polluted water. At increasing distances away from the outfall the oxygen and the number of different species of animals returns to normal levels. Sewage may also carry other pollutants including detergents which may cause foaming and reduce the ability of water to hold dissolved oxygen. Levels of some bacteria may also be high enough to be a risk to health, particularly to swimmers and those eating shellfish caught in the polluted water.

OBJECTIVES

The student will examine the effects and treatment of sewage - one of the most common types of marine pollution in areas of high population.

METHODS

Overhead/handout 20 should be used to show how sewage may be treated and how the effluent affects the marine environment.

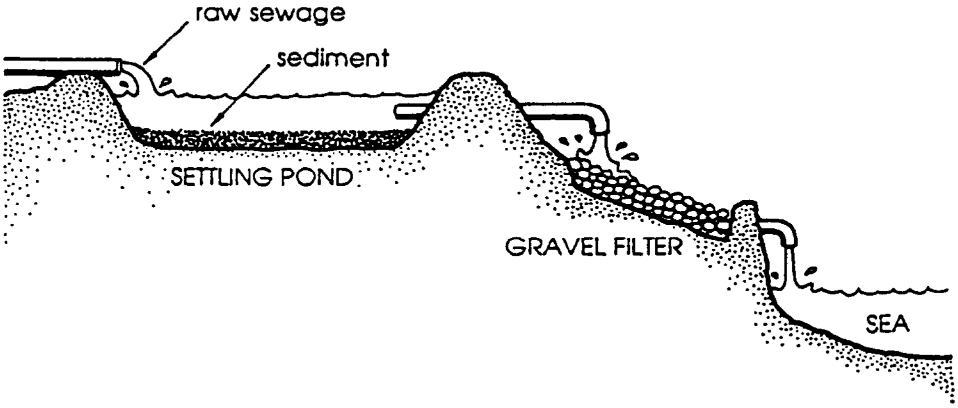
ACTIVITIES/ASSESSMENT

Students should be asked to find out what happens to sewage in a local coastal town, and discuss any effects this has on the coastal environment. A visit to a local sewage treatment works may be arranged by the teacher.

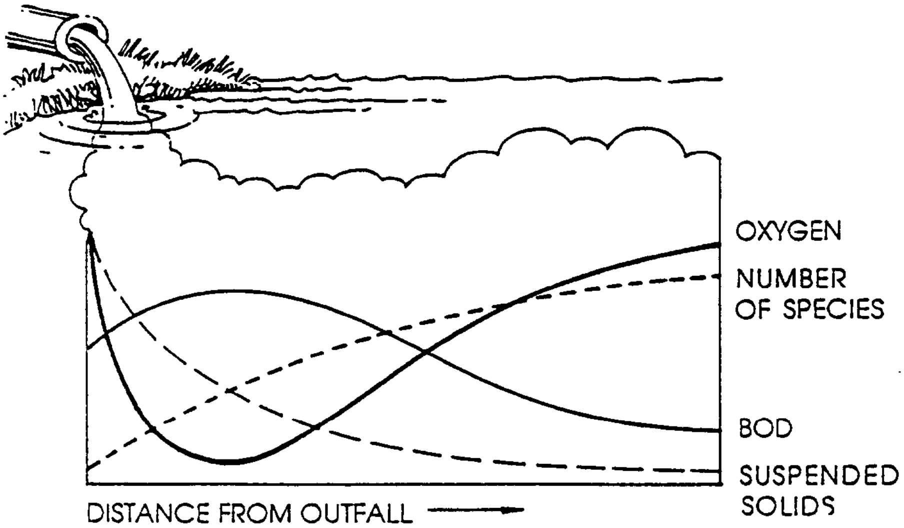
OVERHEAD/HANDOUT 20

VILLAGES, TOWNS and RESORTS

The most common type of pollution in areas of high population is sewage, human faeces and urine, which is released into the sea.



Sewage may be treated in large ponds, like the one above, where much organic material will settle out as a sediment. Passing the remaining liquid through gravel filter beds may remove more suspended organic material.



The figure above shows what is likely to happen to the amount of dissolved oxygen, number of species present, BOD and quantity of suspended solids with increasing distance from a sewer outlet pipe. Close to the outlet there is a large amount of bacteria and the oxygen concentration is low (that is, the water has a high BOD). Very few marine animals can live in such polluted water. At increasing distances away from the outfall the oxygen and the number of different species returns to normal levels.

21. MINING and FORESTRY

BACKGROUND

Mining is important in many coastal countries, and waste material from mines often contain metals which are toxic to plant and animals life. These wastes and considerable quantities of silt are often washed by rain into nearby rivers and coastal areas. The major effect of silt is that it reduces the amount of sunlight penetrating the water, and therefore kills plants and some animals (such as corals) which require sunlight for survival. Silt may also damage the delicate gills of fish.

Forest trees are continually being cut down for local use and for export. In addition forests have been cleared for agriculture and mining, and in many countries, have been disappearing at such a rate that the resource cannot be renewed by natural means. The loss of forests is the loss of an important resource and one which, with good management, should be renewable. An area which has been cleared of trees is subject to land slips and erosion. Without the root systems of trees to hold the earth together, soil is washed away by rain and produces silt pollution in the rivers and sea in the same way as mining.

An alternative to the uncontrolled cutting down of trees, is to have a forest management scheme where forestry is not allowed by rivers or on coastlines. Commercial forestry may be allowed in areas that are not environmentally sensitive as long as trees that are cut down are replaced with seedlings; some countries have successfully created pine plantations for commercial use.

Controls on mining and forestry operations should be part of an Integrated Coastal Management (ICM) plan to protect the coastal environment (see section 18 on the relationship between ecosystems). Management of the coastal environment has to be undertaken on a broad front, with the involvement of many different agencies as well as companies involved in mining and forestry.

OBJECTIVES

The student will be able to understand the effects of silt from mining and forestry operations in coastal waters.

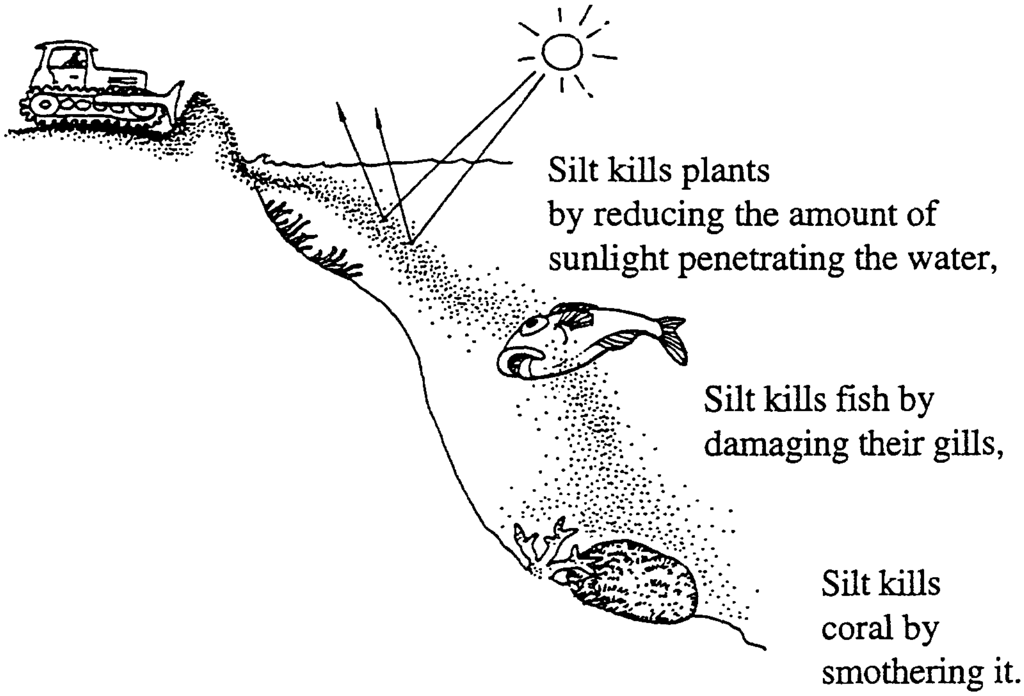
METHODS

Overhead/handout 21 should be used to show the effect of silt from mining and forestry operations in coastal waters. The teacher may take the opportunity to discuss the concept of sustainable yield in forestry; this concept is developed further in relation to fisheries management (overhead/handout 43).

ACTIVITIES/ASSESSMENT

A visit to a local mining and/or forestry operation may be arranged by the teacher. Students should investigate the types of controls placed on these operations to prevent environmental degradation. In the case of mining, the action taken to dispose of mine wastes, should be considered. In the case of forestry, the action taken to prevent erosion, should be considered.

OVERHEAD/HANDOUT 21
MINING and FORESTRY



A forestry company proposes to harvest timber for export from a local area. The question is whether to allow the company to operate without restrictions (A), or to impose some restrictions to protect the resource and the environment (B).

The company proposals are given in the left-hand column and the negative aspects of each action are shown in the second column. Alternative, and less environmentally damaging actions are listed in the third column.

A) NO RESTRICTIONS		B) SOME RESTRICTIONS
ACTION	**RESULT**	**ACTION**
The company wants cut down trees over a wide area. of the coast.	Erosion and landslips will cause siltation.	The government makes reserves on steep hills and near rivers.
The company has no tree replanting programme	The resource will become overexploited.	The company is made made to replant logged areas.

22. AGRICULTURE and INDUSTRY

Clearing land on slopes for growing crops, particularly on a large scale, often creates erosion problems similar to those created by mining and forestry operations (overhead/handout 21). Erosion in the case of agriculture can be avoided by sensible management practices, including the construction of terraces along contours, and by leaving belts of trees across the land (overhead/handout 22).

A most serious problem with agriculture is created by the use of pesticides. Pesticides are poisons used to kill or control pests - organisms which are considered harmful. Those which are used to kill weeds are called herbicides, and those used to kill insects are called insecticides. Problems occur when pesticides are washed away by rain and into rivers and coastal waters. Some pesticides are very stable - that is, they remain unchanged in the environment for a long time. Pesticides in water are particularly harmful to the young or larval stages of marine species. Some pesticides can also become concentrated in the flesh of high level carnivorous fish by the process of biomagnification (see overhead/handout 17). The use of some particularly dangerous pesticides has been banned in many countries, but is still allowed in less developed countries.

Several types of industries including sugarmills, engineering plants and fish and fruit processors discharge their wastes directly into coastal waters. Serious industrial pollutants are cyanide and the metals copper, zinc, lead and mercury. Some of these metals are particularly dangerous because they are cumulative - that is, even small amounts ingested with food material will, over a long period, build up to high concentrations in the organs and flesh of marine animals. Larger carnivorous fish, may gain even higher concentrations by biomagnification though the food chains, and become extremely toxic to human beings.

Although less toxic, oil can be a serious pollutant released by certain shore installations and by ships. Oil forms a thin film on the surface of the water which may cover and kill coral and other intertidal animals attached to rocks.

Controls on coastal agriculture and industry should be part of any Integrated Coastal Management (ICM) plan to protect the marine environment (see section 18 on the inter-dependence of ecosystems).

OBJECTIVES

The student will be able to appreciate the effects of agriculture and industry on the marine environment.

METHODS

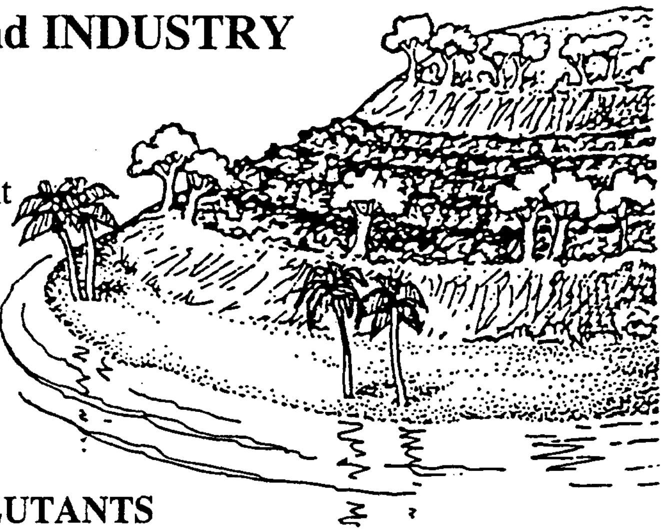
The teacher should encourage discussions on the effects of agriculture and industry on the marine environment. Overhead/handout 22 should be used to show agricultural practices designed to prevent erosion.

ACTIVITIES/ASSESSMENT

Students could undertake to find out the types of insecticides being used in local coastal agriculture, and the types of wastes being discharged into the sea by local industries. The likely effects of these pollutants on the marine ecosystem should be discussed.

OVERHEAD/HANDOUT 22

AGRICULTURE and INDUSTRY



The plantation shown on the right has terraces built around the mountain side. Trees are left on the edges of the banks to prevent erosion and land slip.

AGRICULTURAL POLLUTANTS

PESTICIDES, HERBICIDES & INSECTICIDES

Pesticides are poisons used to kill or control pests - organisms which are considered harmful. Those which are used to kill weeds are called herbicides, and those used to kill insects are called insecticides.

Problems occur when pesticides are washed away by rain and into rivers and coastal waters. Some pesticides are very stable - that is, they remain unchanged in the environment for a long time. Pesticides in water are particularly harmful to the young or larval stages of marine species.

INDUSTRIAL POLLUTANTS

HEAVY METALS

Serious industrial pollutants are cyanide and the metals copper, zinc, lead and mercury. Some of these metals are particularly dangerous because they are cumulative - that is, even small amounts in water will, over a long period, become more concentrated in the flesh of edible marine animals.

OIL

Although less toxic, oil can be a serious pollutant released by certain shore installations and by ships. Oil forms a thin film on the surface of the water which may cover and kill coral and other intertidal animals attached to rocks.

23. DEVELOPMENT - destructive or beneficial?

BACKGROUND

People of all countries have a right to expect development. They expect to have such things as buses, roads, electric power, sewerage systems and a clean water supply. To a greater or lesser extent, all of these benefits will affect the environment in a destructive way. The problem is how to have the most benefit with the least environmental destruction.

Traditional ways of building, farming and fishing by small populations has had very little effect on the environment. However, with increasing populations and the trend towards a money-based economy, traditional ways are being lost. An area with a large population is under increasing pressure to provide employment and to overexploit natural resources. Development, however, can be balanced so that it is possible to retain the best of the old ways and obtain the best of the new.

Before any new development, such as the building of a tourist resort or a factory, takes place, many governments insist on an Environmental Impact Statement (EIS). This involves a study and eventual report which could include weighing the benefits of the proposed development against the negative effects on the environment. Alternative ways (if any) of meeting the same objectives with less damage to the environment may be proposed. As a result of an environmental impact statement, certain restrictions may be placed on coastal development. This is illustrated in the hypothetical example presented in overhead/handout 23.

OBJECTIVES

The student will be able to appreciate that development can be either destructive or balanced - in the latter case, environmental alteration is minimal and natural resources are protected or exploited wisely.

METHODS

The teacher should describe the types of development in local areas, and emphasise that in each case, development can be either destructive or balanced. The table in overhead/handout 23 should be used as a format to discuss other examples of development.

ACTIVITIES/ASSESSMENT

Overhead/handout 23 could be used to as a hypothetical example of minimising the impact of coastal development. In the example, a company proposes to build a tourist hotel with a road to the nearby village. The benefits are obvious; the hotel will bring in foreign money and provide employment for local people. An environmental impact statement, however, suggests some negative aspects of the specific proposals.

The proposed actions of the company are given in the left-hand column of overhead/handout 23, and the negative aspects of each action are shown in the second column. In an effort to reduce the environmental impact of the development, controls in the form of actions, such as those listed in the third column, need to be imposed.

OVERHEAD/HANDOUT 23

DEVELOPMENT - destructive or beneficial?

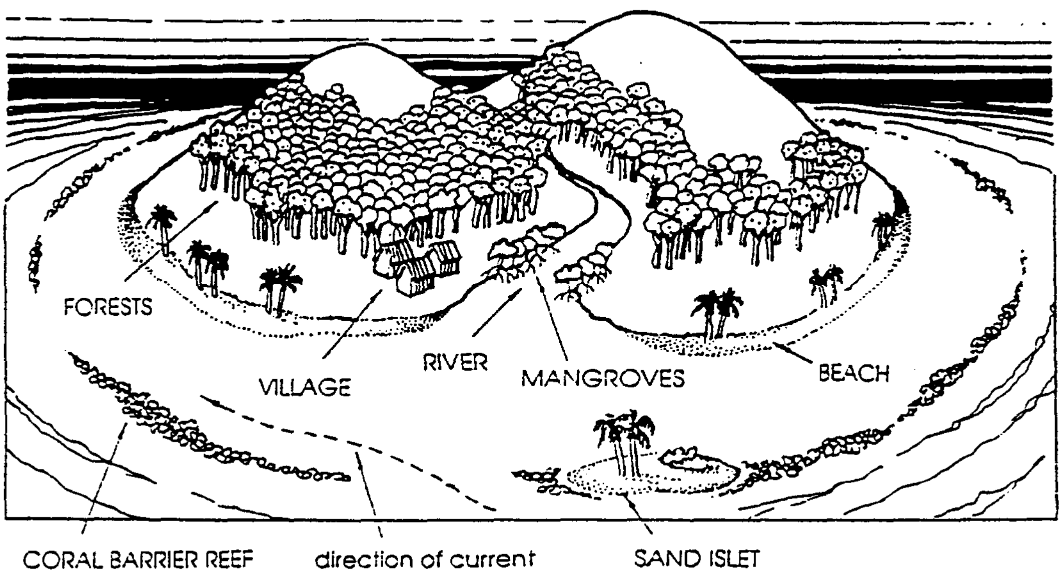
An environmental impact statement could include:

a) The reason for the development,

b) A description of the proposed development,

c) A description of the local environment, and the likely effects of the development, and,

d) A description of alternative ways (if any) of meeting the same objectives with less damage to the environment.



A company proposes to build a tourist hotel on East Beach (shown above) with a road to the nearby village. The company proposals are given in the left-hand column and the negative aspects of each action are shown in the second column. Alternative, and less environmentally damaging, actions are listed in the third column.

NO CONTROLS		SOME CONTROLS
ACTION	**RESULT**	**ACTION**
The company wants to build a road on a causeway over the river near the coast.	The mangroves behind the causeway die because the tidal flow is restricted.	The company is made to build a bridge which does not restrict the tidal flow.
The company wants to pump raw sewage into the lagoon from the hotel.	The current will carry sewage to the coast near the village.	The company is made to install a sewage treatment plant.

FISHERIES

Although available statistics are poor, the annual commercial catch from the fisheries of the world is approaching 100 million tonnes, a figure which has often been regarded as close to the sustainable limit.

In temperate waters of the northern hemisphere, fish stocks of a small number of desirable species have been fished commercially for centuries. In tropical waters, smaller catches of a much larger range of species are caught more commonly as a critical source of protein, rather than as a source of income. In many countries, subsistence fishing, the catching of fish to eat rather than to sell, results in a total catch that is often several times larger than that from commercial fishing.

Seafood is a major food item in many countries. In coastal regions of southeastern Asia and in tropical islands, for example, seafood consumption is often over 50 kg per person each year (compared with a mean of about 12 kg per person for the world), and in low-lying coral islands where soils are too poor to support intensive agriculture, seafood consumption is often over 150 kg per person per year.

As well as more fish being caught by an increasing number of people, fishing methods have become more efficient. The introduction of new types of boats and fishing gear has not only increased pressure on existing resources but has allowed access to previously inaccessible fish stocks. Many fish stocks have been overexploited. A fish stock may be regarded as overexploited when the numbers of fish are reduced to such an extent that the remaining adults are unable to produce enough young fish to maintain the stock. The Antarctic baleen whale, the Peruvian anchoveta, the North Sea herring and mackerel, and the Australian southern school shark have all been dramatically overexploited. Some particularly vulnerable species, such as the giant clam, have been driven to extinction in several areas.

In the past, when populations were small, and fishing methods were less efficient, catches made by one person had very little effect on catches made by others. But the human population and its demand for seafood have grown beyond that which can be supported by finite resources. In addition, there are other claims on the marine environment from recreation, development and industry. The dilemma is, that as demand for fisheries resources is increasing, the ability of the marine environment to sustain them may be decreasing. The freedom to catch fish, or to use the marine environment, without control is now more than likely to be at the expense of someone else's freedom to do the same thing. Some of these freedoms must be sacrificed to allow the continuing use of the marine environment and its resources by present and future generations. The renewability of fisheries resources depends on accepting controls which not only protect fish stocks, but ensure that the environment in which they live does not deteriorate. The main problem is not in enforcing fisheries regulations, but in convincing the community that they are necessary.

A fishery exists in a milieu of a complex set of interactions between the environment, the target species and the people involved in fishing, handling the catch, and managing the resource. The study of fisheries is therefore equally complex, and includes the broad disciplines of oceanography, ecology, biology, gear technology, seafood science, economics, sociology and politics. This section provides an introduction to marine resource species, fishing methods and fisheries management.

24-25. WHAT IS A FISHERY?

BACKGROUND

A fishery comprises a complex set of interactions between the environment, the species fished and the people involved in fishing and handling the catch (overhead/handout 24).

A fish stock, or fisheries resource, is a population of fish, or other marine animal, which is exploited. The different types, or species, which are commonly fished are described in overhead/handout 25.

A fishing operation may be a simple one, such as the hand collection of sea snails on a reef, or a much more complicated one, such as the catching of tuna by a large fishing vessel. Fishing methods are described in detail in overhead/handout 38-41.

The post-harvest handling of the catch may range from basic treatment, such as the storage of fish on ice, to the technologically more sophisticated procedure of canning.

Marketing may refer simply to the sale of fish from a local market but, in the case of exported seafood, involves securing overseas sales as well as transporting the catch in good condition to foreign countries.

Fisheries are often divided into non-commercial and commercial sectors. The non-commercial or subsistence sector involves the catching of fish to eat rather than to sell. The commercial fishery may be divided into an artisanal sector, usually small-scale fishing to supply local markets and an industrial sector, involving large-scale fishing for canneries and export.

Subsistence fisheries provide an important source of protein in many coastal areas and islands. The total catch from subsistence fishing may be several times larger than that from commercial fishing. Although in terms of participation, production, and local use, subsistence fishing represents a most important sector, governments generally do not have adequate funds to survey the large number of participants or the catch species involved.

Artisanal fisheries involve small-scale fishing to supply local markets. In centres of high population, artisanal fishing is an important source of employment. These fisheries often concentrate on relatively few species which may be subject to overfishing.

Industrial fisheries, such as the large-scale fishing for species such as tuna, often supply an export market and add considerably to foreign capital reserves.

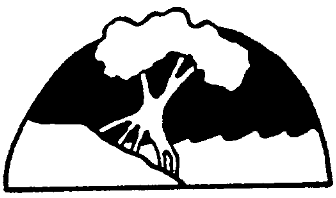
The farming, or aquaculture, of species such as shrimps and oysters has been carried out on a small scale in several countries. The danger is that planners mistakenly believe that aquaculture will provide a source of seafood when natural resources have been depleted. Most types of tropical aquaculture, however, depend on wild stocks to provide juveniles or breeding adults; in addition, providing food for farmed stocks often makes aquaculture very expensive.

OVERHEAD/HANDOUT 24

WHAT IS A FISHERY?

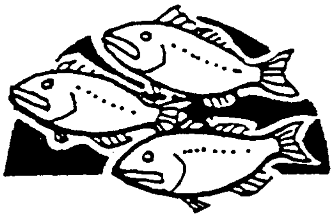
The components of a fishery are;

THE MARINE ENVIRONMENT



The environment of a species includes both physical and biological components of its surroundings. A healthy marine environment is essential to ensure the well-being of fish stocks.

A FISH STOCK

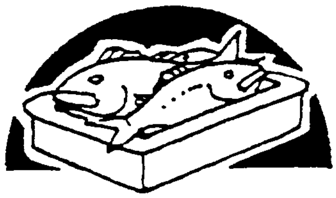


A fish stock, or fisheries resource, is a population of fish, or other marine animal, which is exploited by a fishing operation.

A FISHING OPERATION

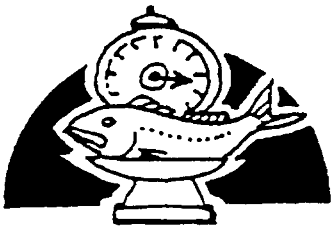
A fishing operation refers to the use of a particular boat, gear and method to catch fish. This may range from the hand collection of molluscs to the catching of tuna by a large fishing vessel.

CATCH HANDLING



The post-harvest handling of the catch may range from the simple storage of fish on ice to the technologically more complex procedure of canning.

MARKETING



Marketing includes the sale of fish from local markets, and the export of seafood to foreign countries.

Subsistence fisheries involve catching fish to eat rather than to sell.
Artisanal fisheries involve small-scale fishing to supply local markets.
Industrial fisheries involve large-scale fishing for canneries and export.
Aquaculture involves the farming of suitable aquatic species.

In spite of the large diversity of marine species, most exploited species are contained in one of four large scientific groups, or phyla. Species are included in a particular phylum 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 describe some members of these four groups including the three invertebrate phyla, Mollusca (including clams, sea-snails and squid), Crustacea (shrimps, shrimps, lobsters, and crabs), and Echinodermata (sea cucumbers and sea urchins), and one vertebrate group, fish. Each section provides a brief description of the general biological characteristics of the group, with examples of some commercially important species and typical life-cycles.

OBJECTIVES

The student will be able to a) understand the complexity of a fishery and become familiar with the terms used in overhead/handout 24, b) recognise the four major groups of marine species used as food, and c) identify examples of local marine species in each of the four groups.

METHODS

Overhead/handout 24 should be used to show the components of a fishery. The teacher should use a well-known local fishery to describe the relevant marine environment, the resource, the fishing methods, and ways of handling and marketing the catch.

The teacher should emphasise the importance of the marine environment on which various resource species depend, and encourage discussions on ways in which the marine environment is being damaged, not only by pollution, but possibly by the fishing activity itself.

Overhead/handout 25 should be used to show the four major groups of marine species. The teacher should obtain mollusc shells and preserved specimens (or at least photographs) to illustrate the range of species within each group.

ACTIVITIES/ASSESSMENT

Students should be asked to describe a local fishery in terms of the components shown in overhead/handout 24, and the type of marine environment in which the resources species are found.

If possible, the teacher should arrange a class visit to a local fishing centre and market. Emphasis should be focussed on the range of resource species, the fishing methods, and the ways of handling and marketing the catch.

Students may carry out a seafood consumption survey of people in their local area. A questionnaire asking details on the number of people in each household, the amount of seafood consumed, the type (molluscs, crustaceans, fish or others), and the proportion caught by members of the family, should be designed. Ideally the survey should be repeated on a regular basis to detect seasonal difference in seafood availability.

OVERHEAD/HANDOUT 25

WHAT IS A FISHERY? - resource species

Most resource species are included in just four large scientific groups.

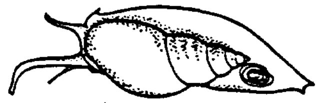
ECHINODERMS

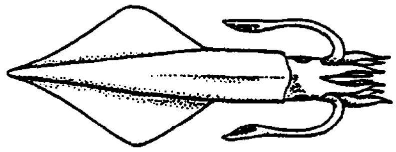
SEA URCHINS 

SEA CUCUMBERS 

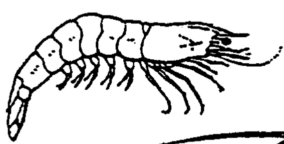
MOLLUSCS

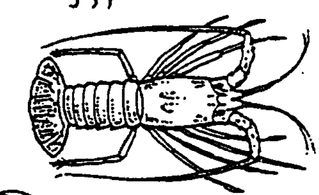
BIVALVES 

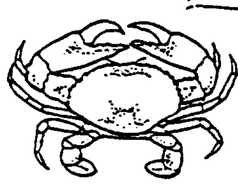
GASTROPODS 

CEPHALOPODS 

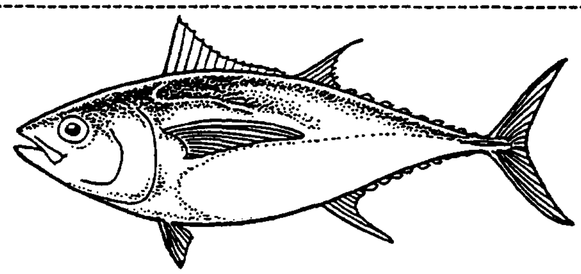
CRUSTACEANS

PRAWNS 

LOBSTERS 

CRABS 

FISH



UNESCO-UNEP International Environmental Education Programme (IEEP)
The Oceans and Coastal Areas and their Resources. M.King and S.King.
UNEP

26. ECHINODERMS - sea cucumbers and sea urchins

BACKGROUND

The phylum Echinodermata contains approximately 5300 marine species, including sea lillies, sea stars, sea cucumbers and sea urchins. Two of the five classes of the phylum Echinodermata (overhead/handout 26), the holothurians (sea cucumbers) and echinoderms (sea urchins), include species which are the bases of valuable export fisheries, and are widely used artisanally. The crown-of-thorns sea star, *Acanthaster planci,* is also included in overhead/handout 26 as it feeds on coral polyps, and has damaged coral reefs in areas of the Indo-Pacific. Large population increases of crown-of-thorns have been associated with increased pollution in coastal areas.

Sea cucumbers, include approximately 1200 species, of which perhaps 15 species are used as food. Sea cucumbers typically have a thick muscular body wall, which forms the edible part of the animal. Mobile sea cucumbers are deposit feeders, and move across the bottom ingesting sand from which the organic material is removed before being expelled as castings. When under stress, or under attack by a predator, sea cucumbers are able to eviscerate their intestinal tract and respiratory tree, possibly as a defence, and regrow these organs. Selected species of sea cucumbers, which are boiled, smoked and dried, are exported to markets in Southeast Asia as beche-de-mer or trepang.

There are approximately 800 related animals commonly called sea urchins, heart urchins, and sand dollars. Sea urchins have globular bodies covered by a shell or test with the mouth directed downwards towards the substrate, and the anus directed upwards. The body is arranged radially in five-parts around the mouth-anus axis, with five areas containing tube feet. The tube feet, which end in suckers, are operated by an internal water vascular system. The movable spines of sea urchins vary between species. The pin-like spines of the tropical hat-pin urchin, *Diadema,* reach lengths of over 30 cm, and contain toxins capable of inflicting a painful wound. The spines of the slate-pencil urchin, *Heterocentrotus,* on the other hand, are blunt, and are adapted for wedging the animal into crevices on coral reefs (overhead/handout 26). Sea urchins feed on algae and small animals using a specialised apparatus called Aristotle's lantern (in honour of the Greek naturalist and philosopher). This apparatus includes five calcareous plates (pyramids) which support five band-like teeth. Sea urchins have separate sexes, and five gonads are suspended on the inside of the test, or shell (see overhead/handout 26).

OBJECTIVES

The student will be able to recognise sea stars, sea cucumbers and sea urchins and understand their biology and importance in marine ecosystems and fisheries.

METHODS

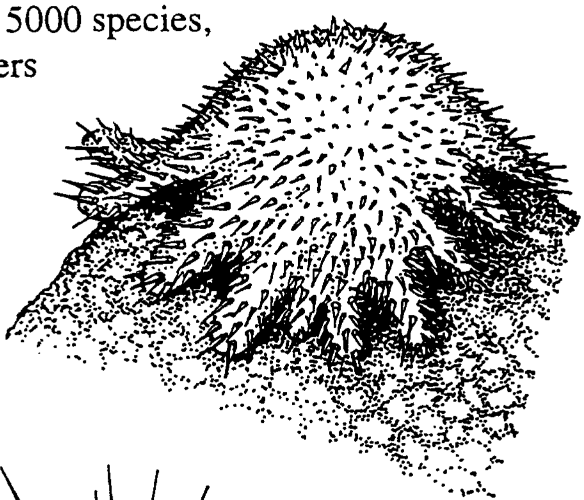
Overhead/handout 26 should be used to show the general form of sea stars, sea cucumbers and sea urchins. If possible, the teacher should obtain several dried sea urchin tests (shells) to demonstrate the general structure of the animals.

ACTIVITIES/ASSESSMENT

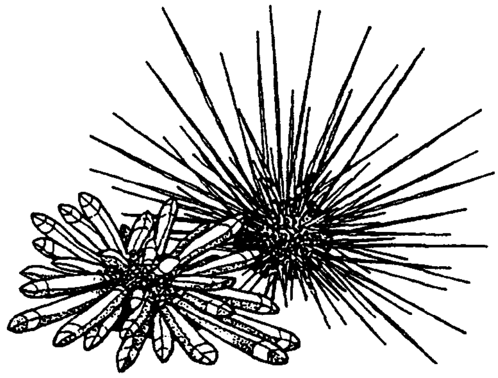
Biology students should be asked to draw and label the structure of a sea urchin as shown in overhead/handout 26.

OVERHEAD/HANDOUT 26

ECHINODERMS. Over 5000 species, including sea stars, sea cucumbers and sea urchins, typically with an internal skeleton, or test, of calcium carbonate.



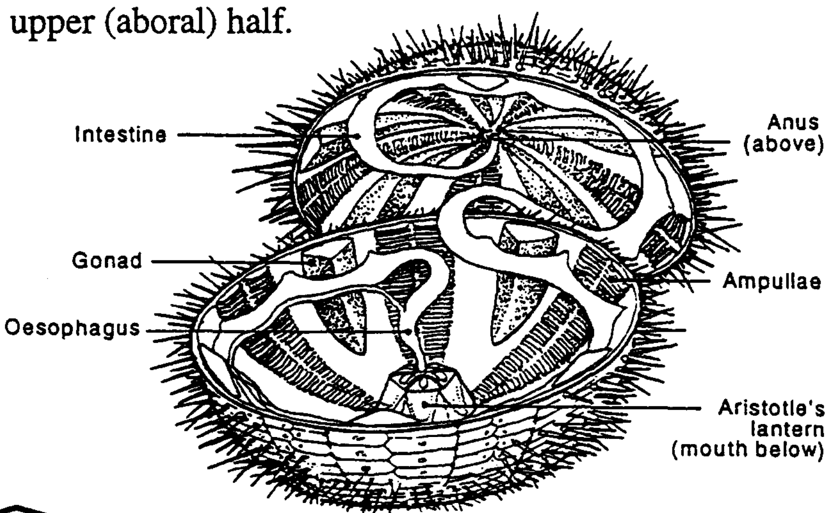
Crown-of-thorns sea star, *Acanthaster planci.*



Hat pin urchin, *Diadema,* and the slate-pencil urchin, *Heterocentrotus*

Sea cucumbers, or beche-de-mer, *Thelanota ananas.*

THE STRUCTURE OF A SEA URCHIN. A sea urchin cut around the side to show the internal structures of the lower (oral) half, and the upper (aboral) half.



27-30. MOLLUSCS - clams, sea snails, squids and octopuses

BACKGROUND

Molluscs, which number more than 65 000 different living species, form a group of great diversity. The phylum Mollusca includes creatures as different as the periwinkle, giant clam and octopus. These diverse animals are related by being soft bodied with organs covered by a sheet of tissue called the mantle, and in having similar larval stages. In most molluscs, the eggs develop into trochophore larvae which pass through veliger larval stages to adult forms. Although the most obvious molluscan characteristic is often one or two shells secreted by specialised cells in the mantle, not all molluscs have shells. Of the five classes of the phylum Mollusca, the bivalves, the gastropods and cephalopods are important in fisheries.

Bivalves (two-shelled molluscs)

The class Bivalvia contains highly-regarded food species such as cockles, clams, oysters, mussels, and scallops. Some species are known for other reasons; the shipworm, *Teredo,* for example, is a wood-boring bivalve which causes costly damage to wooden vessels and wharves. Bivalve molluscs have two shells, or valves, joined together dorsally by a horny ligament called the hinge. The two shells are usually prevented from sideways movement by sockets and grooves ("teeth") located on the hinge line of the shells, and are held together by one or two adductor muscles. When the adductor muscles are relaxed, the interior ligament forces the shells to gape open.

The soft body of a bivalve is enclosed by two lobes of sheet-like tissue (the mantle), which lie between the body and the shells. In many species the mantle lobes are joined together at their outer perimeter except in two areas, the inhalant and exhalant openings. In some burrowing species, these openings are extended into two tube-like processes, the inhalant and exhalant siphons.

Bivalves are filter feeders, and most species obtain food by sifting either microscopic plants from the surrounding water (suspension-feeders), or organic material from the substrate (deposit-feeders). Most bivalves have enlarged gills which have the dual function of food collection and gaseous exchange. Water is drawn in through the inhalant aperture into the mantle cavity by the action of hair-like cilia which cover the gills, and is pumped out through the exhalant aperture. Food material is passed along the gill surface to ciliated labial palps, one pair on each side of the mouth before entering the stomach. The anus is positioned so that waste material and faeces are expelled into the water which passes out through the exhalant aperture (see oyster in overhead/handout 28).

Although most bivalves have separate sexes, several commercially important species are hermaphroditic (have both male and female gonads). In most bivalves, eggs and sperm are released through the exhalant aperture directly into the sea where fertilisation takes place. After fertilisation, eggs hatch to trocophore larvae, which are succeeded by veliger larvae, and often remain in the plankton for several weeks before settling as adult forms. Of the large numbers of eggs released, many millions in some species, a much smaller number become fertilised, and the resulting larvae have to survive high predation rates while in the plankton. In addition, the floating larvae are subject to variable winds and currents which affect the probabilities of reaching suitable substrates on which to settle.

The giant clam is used as an example of a bivalve life-cycle in overhead/handout 27. Giant clams (*Tridacna* species) include the world's largest bivalves, with *Tridacna gigas* reaching weights of up to 250 kg in a lifespan of over 100 years. In South-east Asia, the dried muscles of giant clams are highly valued, and boats from this region have historically fished in the tropical Indo-Pacific. Illegal fishing for clams still occurs, contributing to the decline of clam stocks in some localities.

Giant clams begin life as males, and mature at about two years of age, after which they function as both males and females. At low latitudes, spawning occurs during the summer months when clams, detecting the presence of eggs in the water, forcibly eject sperm through the exhalant aperture. About 30 minutes after releasing sperm, an individual clam releases its own eggs, thereby avoiding self-fertilisation. The eggs hatch into ciliated trochophore larvae after about 12 hours, and these develop into a shelled veliger stage about two days after fertilisation. The veliger develops a foot (becomes a pediveliger) and alternates between being in the water column and on the substrate. Advanced veliger larvae finally settle permanently on the substrate within ten days of being released. All giant clams are initially attached to the substrate by byssal threads. The larger species lose this attachment and remain in place by virtue of the weight of the massive shells.

Giant clams are unique among bivalves in that they are able to obtain nutrients from a relationship with microscopic plant cells called zooxanthellae. Free-living zooxanthellae become established in the mantle of the larval clam (the pediveliger) after settlement. After this, the now symbiotic plant cells photosynthesise and produce nutrients which are used as food by the clam. This symbiotic relationship is evident in some other tropical invertebrates, including most shallow-water corals.

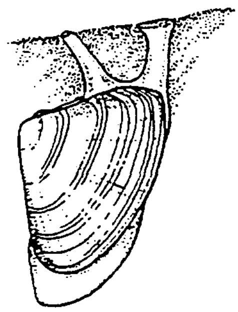
Some bivalve and gastropod species have a shell with an inner nacreous (or mother-of-pearl) layer. In some cases, sand grains or parasites which manage to get between the shell and the mantle act as irritants. The mantle may then produce concentric layers of nacreous shell around the object, which eventually becomes a blister, or half-pearl, on the inside of the shell. Less commonly, a free spherical pearl may be formed. Although pearls can be formed by many bivalve species, commercially valuable pearls are only produced by those whose shells have nacreous layers with desirable reflective properties; in particular, the pearl oysters of the genus *Pinctada* (overhead/handout 27).

Many bivalves are ideal candidates for aquaculture because of their sessile (non-mobile) nature, and ability to filter food from passing water currents. Oysters and mussels are two of the most successfully farmed groups of bivalves in the world. The farming of giant clams in shallow ponds is aimed at restocking reefs where they have been over-fished. Through their symbiotic relationship with zooxanthellae, giant clams are unique in being the only farmed marine animals which can feed indirectly from sunlight.

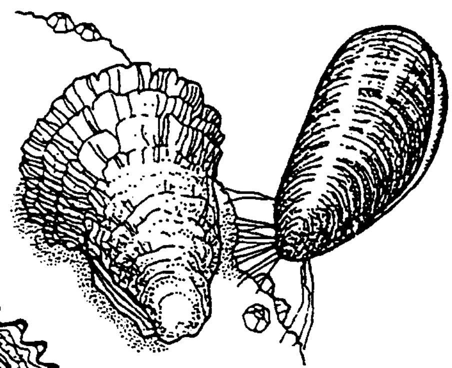
In many coastal communities, where fish is an important source of protein, intertidal bivalves are used by subsistence fishers as an alternative seafood in times of bad weather. In some coastal communities, for example, the weight of bivalves caught is greater than that of any single family of fish species.

OVERHEAD/HANDOUT 27

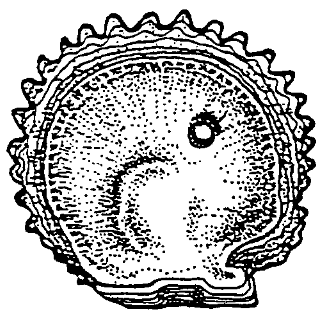
MOLLUSCS - bivalves. Approximately 10 000 species with two shells, and the ability to obtain food by filtering microscopic plant cells from the surrounding water.



Surf clam, *Donax deltoides,* with siphons.

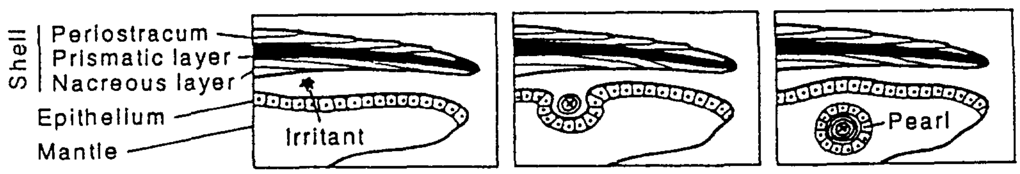


Pacific oyster, *Crassostrea gigas,* and a mussel, *Mytilus.* attached to the substrate.

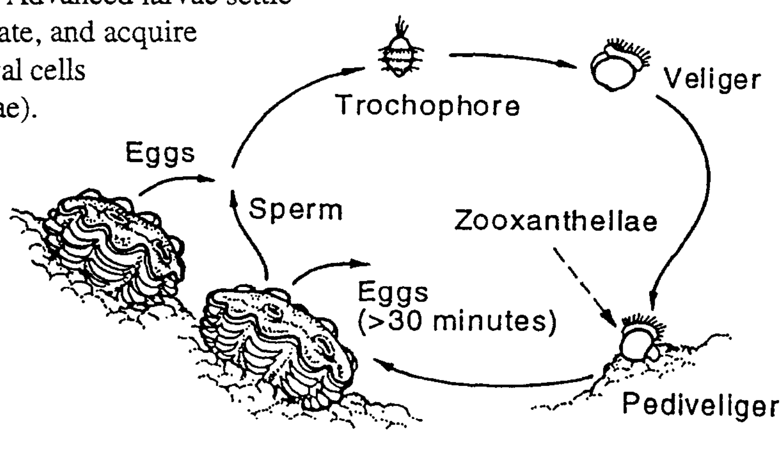


Black-lip pearl-oyster, *Pinctada margaritifera,* with pearl.

The sequence of pearl formation in bivalves: an irritant between the shell and the mantle is enveloped by the mantle, which produces a pearl, concentric layers of nacreous shell, around the irritant.



THE LIFE CYCLE OF GIANT CLAMS: Giant clams are hermaphroditic (function as both males and females), but release sperm and eggs at different times. After the eggs hatch, the larvae develop through several larval stages. Advanced larvae settle on the substrate, and acquire symbiotic algal cells (zooxanthellae).



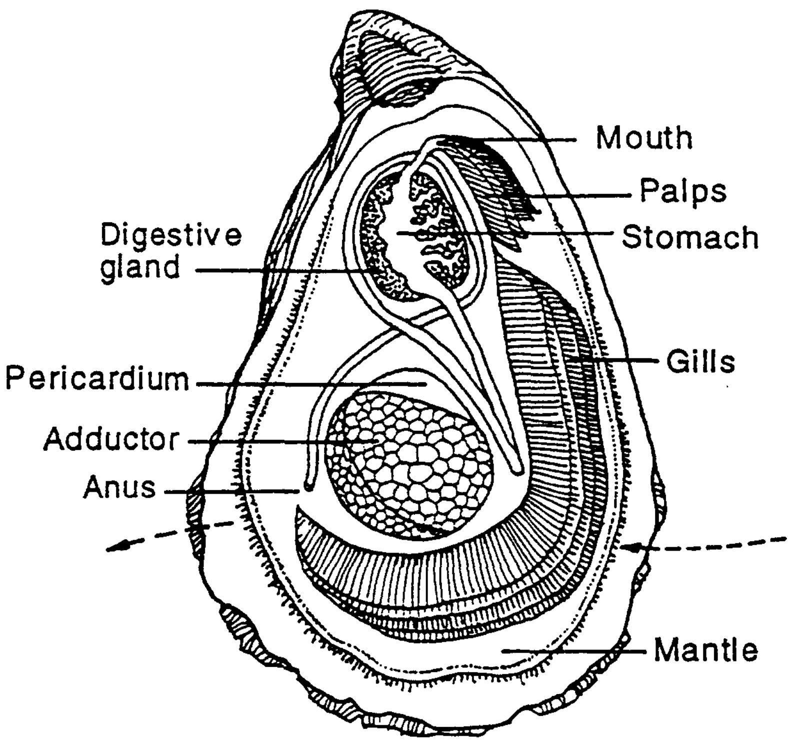
OVERHEAD/HANDOUT 28

MOLLUSCS - the dissection of a bivalve.

AIM: To observe the structure of a bivalve mollusc (an oyster).

BACKGROUND: Bivalves are particularly important in coastal ecosystems, as they feed on suspended phytoplankton, and provide a link in the food chain between primary production and carnivores.

METHODS: Remove the right-hand shell (or valve) by cutting the adductor muscle between the shell and the mantle. Do this carefully to avoid damaging the structures beneath. Remove the mantle with a fine pair of scissors. Observe, draw and label the structures shown in the diagram below.



Water (flow shown by arrows) passes over the gills, which trap phytoplankton and collect oxygen. Phytoplankton is collected on the gills and passed to the mouth, between the palps. Digested food is passed from the anus into the surrounding sea water.

Gastropods (sea-snails)

The class Gastropoda is the largest class of molluscs. Many of the 80000 species have evolved for life in different habitats, and can be found in the open ocean, in fresh water and on land. Most species used as food, however, inhabit shallow coastal areas, particularly rocky or coral reefs.

Although some gastropods, such as sea slugs (nudibranchs), have no shell, most species of commercial interest have a single shell. The typical shell is conical with the oldest part of the shell at the apex. The head often has tentacles and eyes, and the foot, in many species, bears a disk, called the operculum, on its posterior dorsal surface. As the foot is retracted into the shell, the operculum forms a protective door to the shell opening. Most gastropods crawl or glide by means of their muscular foot which is lubricated by special mucus glands.

All molluscs, except for bivalves, have teeth arranged in rows along a file-like flexible strip called the radula. The radular teeth of gastropods are adapted for a variety of feeding methods in different species. The number of teeth on the radula varies between species from several thousand teeth in some herbivorous gastropods which rasp algae from the substrate, to only a few highly specialised teeth in some carnivorous forms.

The radula of some carnivorous gastropods, such as *Murex,* and the moon snail, *Polinices,* are adapted for drilling holes in the shells of bivalves. The drill-like action of the radula cuts a bevelled hole in the bivalve's shell, and the soft tissues are slashed by the radula and ingested. Carnivorous drilling species are responsible for devastating commercial oyster and cockle beds.

Tropical cone shells (*Conus* species) feed on worms, other gastropods and fish which they harpoon and poison by firing a single barbed radula tooth into their prey. A nerve poison is introduced via the hollow cavity in the tooth, and some species, including *C. textile* and *C. geographicus* are dangerous to humans, if handled carelessly.

Although only a few gastropods, particularly abalone, are the bases of valuable seafood export industries, many other species with a large and fleshy foot are collected as food in coastal areas. Additionally, many gastropod species are valued in the ornamental shell trade and for sale to tourists, because of the diversity in form and colour of their shells. Several gastropod species have shells with a pearly inner (or nacreous) layer. The top shell, *Trochus niloticus,* is collected in the Indo-Pacific and used in the manufacture of buttons for European and Asian markets. Holes are drilled around the spiral shell to produce the circular pieces of shell which are polished to make buttons (see overhead/handout 29).

Cephalopods (octopuses, squids, cuttlefishes)

The class Cephalopoda contains approximately 800 living species of octopus, squid, cuttlefish, and chambered nautilus. Cephalopods include the largest of all invertebrates. Some species of deepwater squid weigh over one tonne, although the average size of commercially caught squid is less than one kilogram. Cephalopods, particularly squids, support the largest catches of all molluscan fisheries, with an annual world landing approaching two million tonnes, comprising mainly of open-sea squid.

In octopuses the shell is absent, and only the *Nautilus* has a completely developed external shell. Squids and cuttlefish have internal shells. The shell in squids is reduced to a transparent "pen" of chitinous material, and in cuttlefish, to a calcified "cuttlebone" of light cellular material which aids in buoyancy. Squids and cuttlefish have evolved for a pelagic existence in the open ocean, and the mantle is often extended into two stabilising fins. All cephalopods, including the octopus which is adapted for life on the sea floor, move through the water using a jet-like propulsion, in which water is drawn into the mantle and expelled through a funnel. The cephalopod head is well developed with the mouth surrounded by arms which, except for *Nautilus,* bears either suckers or hooks, or both. Squids and cuttlefish have eight arms and two longer tentacles, the octopus has eight arms, and the chambered nautilus has many slender arms without suckers. All cephalopods possess a pair of beak-like jaws to hold prey, and the radula which be used to rasp at flesh.

The life-cycles of squids are not well known, do doubt due to the difficulty of studying such seasonal and pelagic species. In general, spawning may occur in both spring and autumn. The broods of immature squid grow rapidly (1 to 2 cm mantle length per month), feeding on planktonic crustaceans, fish and other cephalopods. Approximately one year later, they move into shallow water to reproduce. Mating may be preceded by a courtship display involving colour changes by the male. During mating, the male uses a modified arm (the hectocotylus) to transfer spermatophores (bunches of sperm) from its own mantle cavity to that of the female. The eggs are fertilised by sperm from rupturing spermatophores as they are released by the female, and are often encased in a gelatinous material. The fertilised eggs hatch to miniatures of the adults.

Octopuses, which are usually nocturnal hunters on coral reefs and in rocky areas, are caught using traps, spears and hooks. The most widely distributed species of chambered nautilus, *Nautilus pompilius,* is caught in traps set in deep water for snapper and caridean shrimps, and it is the shell of this species which is usually marketed in the ornamental shell trade. Over 70% of the world total catch of cephalopods consists of squids. Most of this catch is taken by foreign-going Japanese fishing vessels, and the main fishing areas are in the northern parts of the Pacific and Atlantic oceans.

OBJECTIVES

The student will be able to a) recognise the different types of molluscs, b) understand their basic biology, and c) appreciate their importance in marine ecosystems and fisheries.

METHODS

Overhead/handout 27, 29 and 30 should be used to show the diversity of molluscs. If possible, the teacher should obtain a collection of shells to show students. Overhead/handout 28 should be used to show the internal structure of a bivalve. The fact that bivalves feed on suspended phytoplankton, thereby providing an important link in the food chain between primary producers and carnivores, should be stressed.

ACTIVITIES/ASSESSMENT

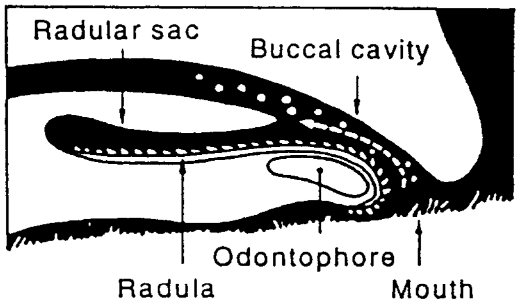
Biology students should be asked to dissect, draw and label the structure of a bivalve mollusc in a similar way to overhead/handout 28. Other activities could include making a collection of the shells of locally occurring marine molluscs, and completing a drawing showing the role of these molluscs in food webs.

OVERHEAD/HANDOUT 29

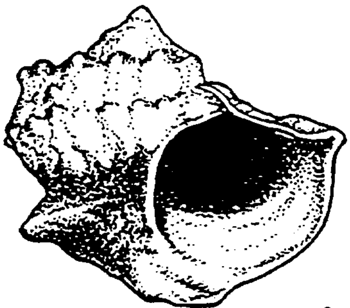
MOLLUSCS - gastropods (sea snails)

Approximately 80 000 species, mostly with a single shell.

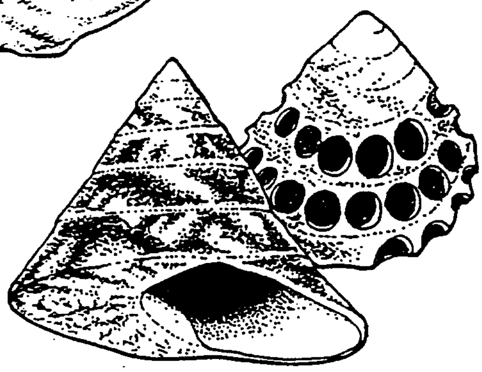
The mouth cavity and radula of a grazing gastropod.



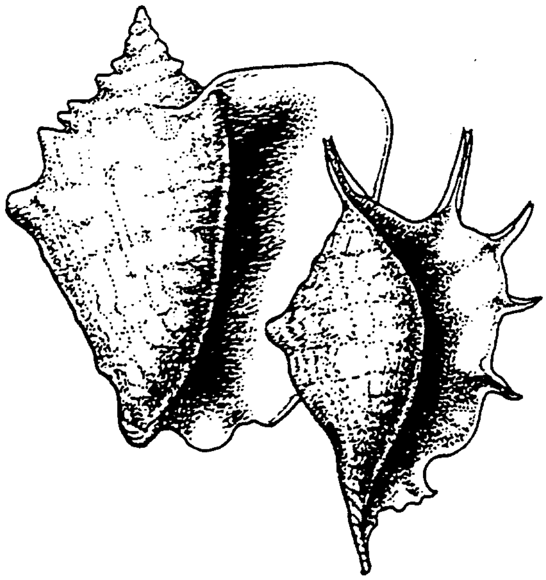
Green snail, *Turbo marmoratus.*



Trochus shells, *Trochus niloticus,* one of which has been drilled to remove circular pieces of shell used to make buttons.

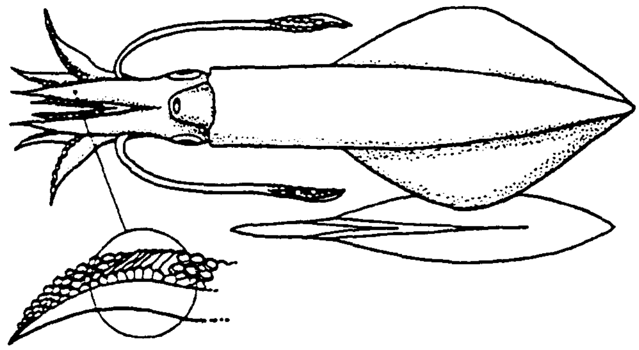


Pink conch, *Strombus gigas,* and the spider shell, *Lambis lambis.*

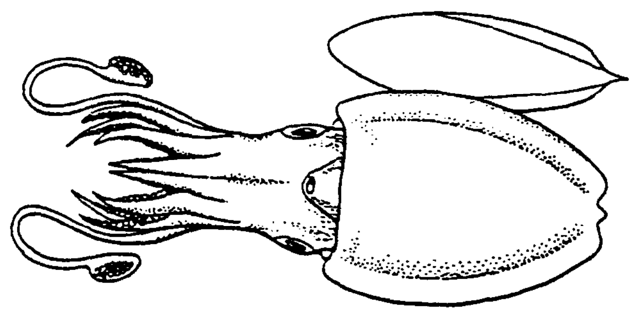


OVERHEAD/HANDOUT 30
MOLLUSCS - cephalopods

About 800 living species of active animals with large eyes and powerful jaws, including the octopus, squid, cuttlefish, and chambered nautilus.

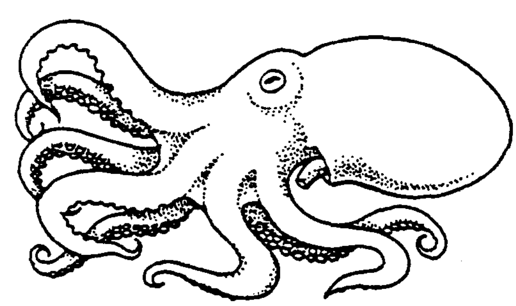


Squid, *Loligo,* showing its internal shell or pen. The inset shows the hectocotylus, the arm used to transfer sperm to the female.

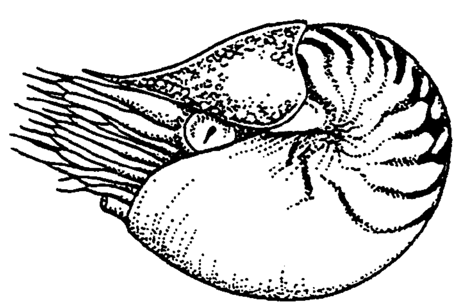


Cuttlefish, *Sepia,* showing its internal shell, or cuttle-bone.

Octopus,
Octopus.



Chambered nautilus,
Nautilus pompilius.



31-32. CRUSTACEANS - shrimps, lobsters and crabs

BACKGROUND

Over 30 000 marine animals including shrimps, lobsters and crabs, together with such animals as sea lice and barnacles, are crustaceans. Many crustacean species, such as copepods and amphipods, remain planktonic for their entire lifespan as part of the zooplankton (the holoplankton). The marine copepod *Calanus,* for example, is one of the most abundant animals in the world, and is of great importance in marine foodwebs, feeding on a biomass of phytoplankton that is perhaps five times larger than that of all terrestrial vegetation. Other crustaceans, like most other marine organisms, have early larval forms which are temporarily part of the zooplankton. Crustaceans typically have jointed legs and other appendages attached to a segmented body covered with a hard chitinous shell (or exoskeleton) hardened with calcium carbonate.

Most valuable fisheries are based on the larger decapod (ten legged) crustaceans, which include shrimps, lobsters and crabs. These have a carapace which encloses a fused head and thorax (the cephalothorax), and an abdomen which consists of six segments. There are, generally, five pairs of walking legs (pereiopods) attached to the cephalothorax, and five pairs of swimming legs (pleopods) attached to the abdomen. In shrimps and lobsters, the cephalothorax is referred to commercially as the "head", and the abdomen as the "tail". A range of crustaceans is shown on overhead/handout 31, with the external features of a penaeid shrimp.

During mating, the males release sperm from genital openings at the base of the fifth pair of walking legs. The male's first pair of swimming legs may be modified for the transfer of sperm clusters (spermatophores) to the female. When spawning occurs, the female releases eggs, and these are fertilised as they pass over the stored sperm. In all commercial crustaceans, except penaeid shrimps, fertilised eggs become attached to the swimming legs beneath the female's abdomen. In penaeid shrimps, fertilised eggs are released directly into the sea, and hatch to nauplius larvae. In other crustaceans which carry broods, the eggs hatch to more advanced larval stages.

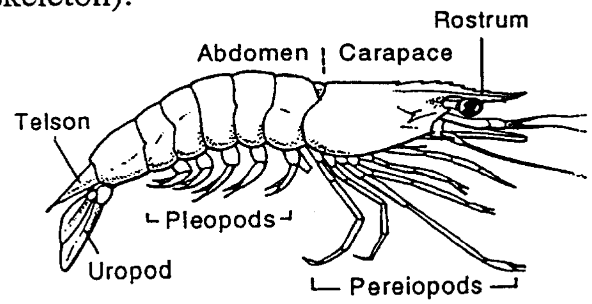
The possession of a hard exoskeleton prevents crustaceans from growing with a gradual increase in size as other animals do. In order to grow in size, a crustacean must periodically cast off its restrictive exoskeleton, and expand in the short time before a new and larger shell hardens. This process, called molting, involves several stages (overhead/handout 32). In the premolt stage, a new soft exoskeleton forms beneath the older, hard exoskeleton. Calcium from the old exoskeleton is absorbed into the blood, and the new one becomes tinged with red carotene. In the molt, or ecdysis stage, the old shell splits at fuse lines, one of which is usually at the junction of the cephalothorax and the abdomen, and is shed by the soft-shelled crustacean. In the postmolt stage, the animal expands, assisted by the uptake of water, before the new, larger shell gradually hardens. Calcium salts, in temporary storage in the blood, are deposited in the hardening shell, and as soon as the mandibles are sufficiently hard, the animal feeds voraciously. The animal is particularly vulnerable until its shell fully hardens, and often hides or burrows (depending on the species) to avoid predators. Each molting event is separated by an intermolt period which may be relatively long. During this period, the animal may increase in weight (particularly in the early part of the period), but not in length.

OVERHEAD/HANDOUT 31

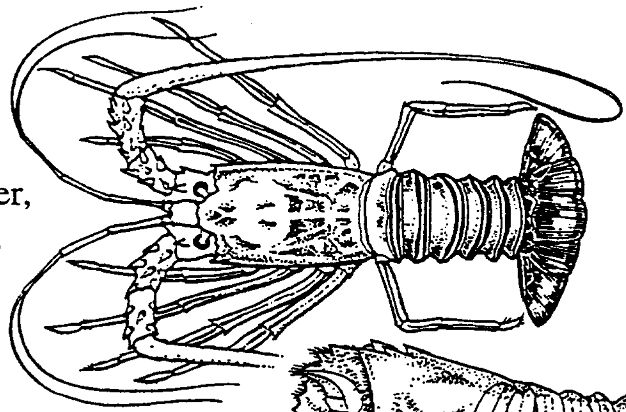
CRUSTACEANS

Over 30 000 species, including shrimps, lobsters and crabs, typically with jointed legs, and a body covered with a hard shell (or exoskeleton).

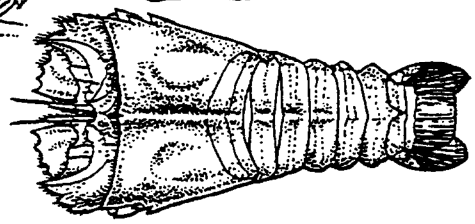
Penaeid shrimp,
Penaeus monodon.



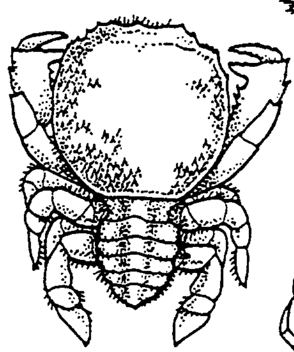
Spiny (painted) lobster,
Panulirus versicolor.



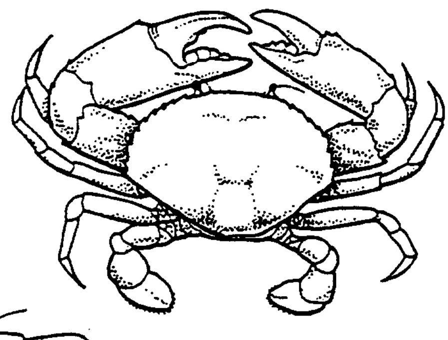
Slipper lobster,
Thenus orientalis.



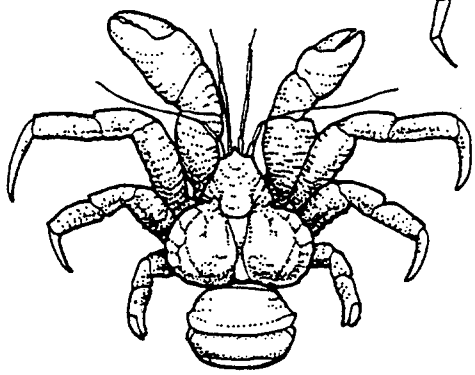
Spanner or kona crab,
Ranina ranina.



Mangrove crab,
Scylla serrata.



Coconut crab,
Birgus latro.



UNESCO-UNEP International Environmental Education Programme (IEEP)
The Oceans and Coastal Areas and their Resources. M.King and S.King.
UNEP

Penaeid shrimps

Although shrimps are capable of swimming, they spend most time on, or close to, the sea floor. They are usually nocturnal, burrowing into the bottom sediments during the day, and emerging to feed at night. As opportunistic omnivores, they feed on a wide range of plant and animal material.

Penaeid shrimps are the basis of valuable trawl fisheries in coastal, warmer waters throughout the world. The distribution of penaeid shrimps is generally restricted to tropical and sub-tropical waters, and because of the requirement of most penaeids for brackish water, they are found only in areas which have sufficient rainfall to produce rivers and estuaries. The farming of shrimps, particularly the giant tiger shrimp, *Penaeus monodon,* is undertaken in many tropical countries, particularly in South-east Asia. Shrimps are either collected as juveniles, or bred in a hatchery, before being placed in shallow water ponds to grow.

There are three types of life-cycle in penaeid shrimps - estuarine, oceanic, and "mixed" estuarine and oceanic. However, most commercially important species of *Penaeus* have a "mixed" life-cycle, in which adult shrimps live and spawn in oceanic waters, and the larvae progress through nauplius, protozoea, and mysis stages before the demersal post-larvae reach inshore creeks and estuaries which act as nursery areas for the juveniles. The life-cycle of a typical shrimp is shown on overhead/handout 32.

Lobsters and crabs

Lobsters and crabs are generally adapted for a benthic habit, and the five pairs of legs are adapted for moving across the substrate rather than swimming. Some species, however, such as the swimming crabs (family Portunidae) and even the slipper lobsters (family Scyllaridae) are able to swim well.

Lobsters

True lobsters, such as those of the genus *Homarus,* have claws, and are the basis of large fisheries in colder waters. However, in subtropical and tropical regions, there are two types of clawless lobsters, the slipper or shovel-nosed lobsters, and the spiny lobsters which are commercially important (overhead/handout 31).

Slipper lobsters of the family are so-named for the flat carapace, and the broad, flattened antennal plates at the front of the head. Some species are caught in shallow water, such as the queen slipper lobster, *Scyllarides squamosus,* which is found on coral reefs. Most other species are taken in deeper waters down to depths of 500 m.

Spiny or rock lobsters of the family Palinuridae lack the claws of true lobsters, such as *Homarus,* but have spine covered carapaces and antennae which are used in defence. Reproduction is similar to that of penaeid shrimps, except that females carry fertilised eggs beneath the abdomen on the swimming legs.

Some species of spiny lobsters are readily caught in baited traps and hoop nets, and these species are the bases of the largest spiny lobster fisheries in the world. However, many species of the genus *Panulirus* appear not to be attracted to bait, and are caught by people fishing with spears and lights.

Crabs

With approximately 4500 species, the true crabs are the most successful of all decapod crustaceans. Species are distributed over a great range of latitudes and depths, and some crabs live in freshwater and even terrestrial habitats. The abdomen of true crabs is usually greatly reduced, and curved tightly up under the cephalothorax. The swimming legs are retained in the female for carrying eggs. Many species of crabs are caught for food merely by hand collection, or by spearing, on shallow-water reefs and in estuaries. Some artisanal fisheries may involve the use of traps and hoop nets.

A primitive group of burrowing crabs includes the spanner or frog crab, *Ranina ranina,* (overhead/handout 31). The spanner crab, which takes its name from the unusual spanner-like shape of its claws, is believed to be present in deeper water from Africa across the Indo-Pacific to Hawaii (where it is known as the Kona crab). Although most crabs have evolved for walking, members of the family Portunidae are powerful swimmers. Members of this family, which contains such commercially important species as the mangrove crab, *Scylla serrata,* have flattened paddles at the end of the last pair of legs.

Some anomuran crabs (not true crabs) are caught for food, and these include the king crab and the coconut crab (overhead/handout 31). The coconut, or robber crab, *Birgus latro,* which spends most of its life-cycle on land, reaches weights of over 4 kg. Although the juveniles are housed within shells as other hermit crabs, the large adults have evolved away from requiring this protection. The adults possess massive crushing claws, and long legs which enable them to climb trees. The diet includes carrion, rotting leaves, fruit, and coconut flesh, and large adults are capable of husking and breaking through the shell of a fallen coconut. The coconut crab is distributed in tropical islands from the Seychelles in the Indian Ocean to the Tuamotu Archipelago in the Pacific Ocean, and is a highly valued food item in many parts of its range. Its vulnerability to domestic and feral animals, and the destruction of its coastal habitat has probably accounted for its disappearance on continents, and its ease of capture has resulted in its depletion in many island countries.

OBJECTIVES

The student will be able to a) recognise the different types of crustaceans, b) understand their basic biology, and c) appreciate their importance in fisheries.

METHODS

Overhead/handout 31 should be used to show the range and characteristics of crustaceans. Overhead/handout 32 should be used to show the life-cycle of a penaeid shrimp and to present the moulting cycle.

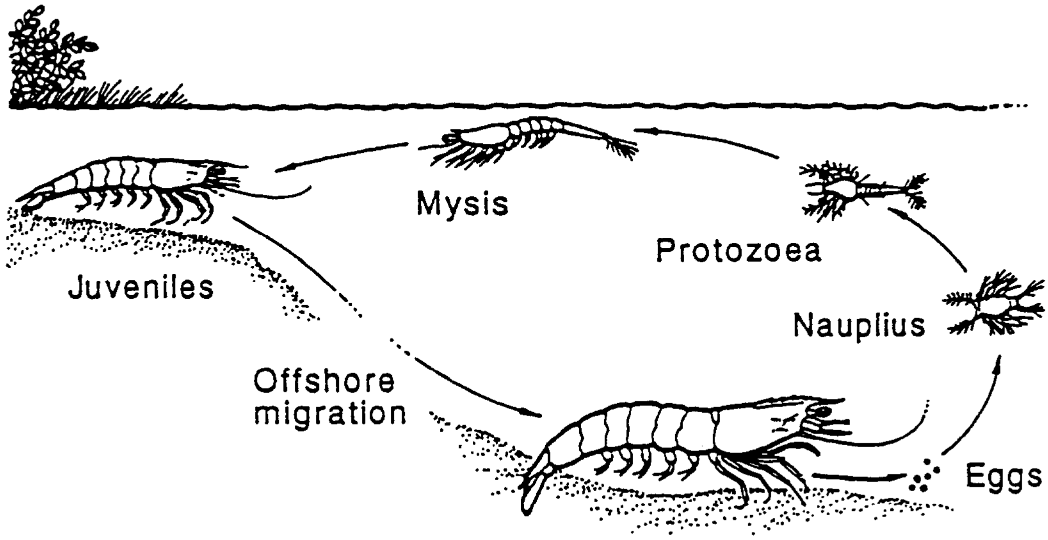
ACTIVITIES/ASSESSMENT

Biology students should be asked to label the external features of a crustacean in a similar way to overhead/handout 31. Other activities could include making a list of crustaceans that are important in local fisheries.

OVERHEAD/HANDOUT 32

CRUSTACEANS - the biology of penaeid shrimps

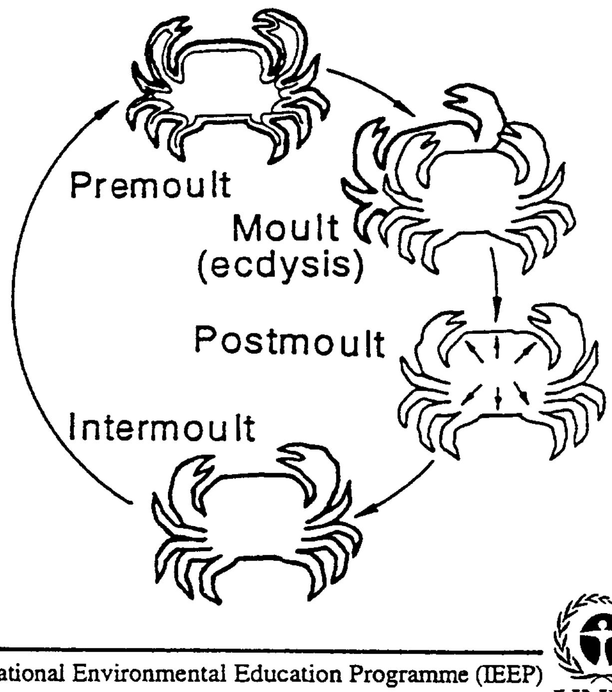
Commercially important shrimps in tropical areas belong to a group known as penaeids. Most penaeids use inshore mangrove creeks and estuaries as nursery areas for the juveniles.



THE LIFE-CYCLE OF A PENAEID SHRIMP.

- Adult shrimps live in deeper water away from the shore.
- During spawning, fertilised eggs are released into the sea.
- Eggs hatch and progress through several planktonic larval forms.
- Larvae drift into inshore nursery areas, often mangrove creeks.
- Larvae grow into sub-adults before migrating out to join the adults.

Stages of the crustacean molt cycle;
premolt, molt (ecdysis), postmolt, and intermolt. The heavy outline represents the hard shell, and the light outline represents the soft shell.



33-37. FISH

BACKGROUND

Almost half of all species of animals with backbones (vertebrates) are fish. There are over 21 000 different species of fish distributed in environments from high mountain pools to the deepest parts of the ocean, and from warm tropical waters to cold polar waters. Fish have two sets of paired fins, the pectoral and pelvic fins, which are believed to be the evolutionary precursors of the four limbs of terrestrial vertebrates. The single fins are the dorsal fin, the anal fin, and the caudal (tail) fin (overhead/handout 33).

Ancient, heavily armoured fishes, evolved along two main evolutionary lines, each of which solved the problem of buoyancy in different ways. In one group, the descendants of modern sharks and rays, the calcified skeleton was replaced by lighter cartilage. Buoyancy in modern sharks is also aided by having a liver which is rich in the low density oil, squalene, and by having fixed pectoral fins which act as paravanes. As the shark moves forward through the water, pressure on the underside of the pectoral fins provides uplift, and prevents the animal from sinking. Thus many species of sharks have to swim continually to stay afloat.

The other evolutionary group, the descendants of present-day bony fishes, retained calcified bones in their skeleton, but solved the problem of remaining buoyant in a different way. The primitive lung acquired by ancient fishes living in shallow, de-oxygenated water evolved into the swim bladder of modern bony fishes, most of which obtain oxygen through their gills. The evolution of the swim-bladder allowed fish to evolve away from speed as a way of life. Pectoral fins, no longer required for aiding flotation, could evolve to allow a greater range of movements. Present-day bony fishes use pectoral fins to hover, to swerve, to swim backwards, and even, in the case of flying-fish, to glide through the air. The ability to take advantage of a variety of ecological niches, to be either demersal (bottom-dwelling) or pelagic (living in the water column, or at the surface), has allowed modern bony fishes to dominate the waters of the world.

Fishes have adapted to many different forms of feeding, including sifting plankton from the water, scraping algae from rocks, eating coral, and catching a wide range of prey. The type of teeth and the spacing of gill rakers are related to the type of food taken; the gill rakers, comb-like structures attached to the inside curve of the gill arches, sift particles of food from the water. The digestive system (overhead/handout 33) includes an S-shaped stomach leading to an intestine which is often longer in herbivores than in carnivores. At the junction of the stomach and the intestine, there are often finger-like sacs, the pyloric ceaca, whose function may include aiding food absorption.

The development of senses in fish depends on their habitat. The eyes of many predatory fish which live in clear water are often large, and presumably sight plays an important part in locating prey. The eyes of many fish appear to be capable of distinguishing colours. The sense of touch is particularly well developed in some species, with sense organs distributed over the entire body, and in the feelers or barbels of species such as catfish and goatfish. As in vertebrates, the ear of a fish is a paired organ of both equilibrium and hearing. The sense of hearing in fish through its inner ears is likely to be poor, and consists of detecting vibrations in the water. The lateral line is also believed to be capable of detecting low-frequency vibrations, as well as pressure changes. The lateral line, which runs longitudinally down each side of a fish, consists of row of pores, connected by a canal running beneath the skin.

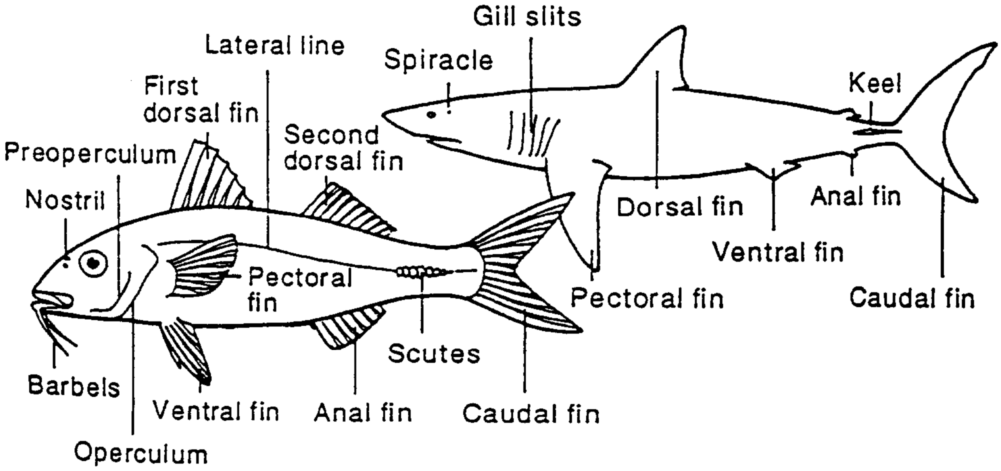
OVERHEAD/HANDOUT 33

FISH DISSECTION

AIM: To observe the external and internal structure of a fish.

METHODS:

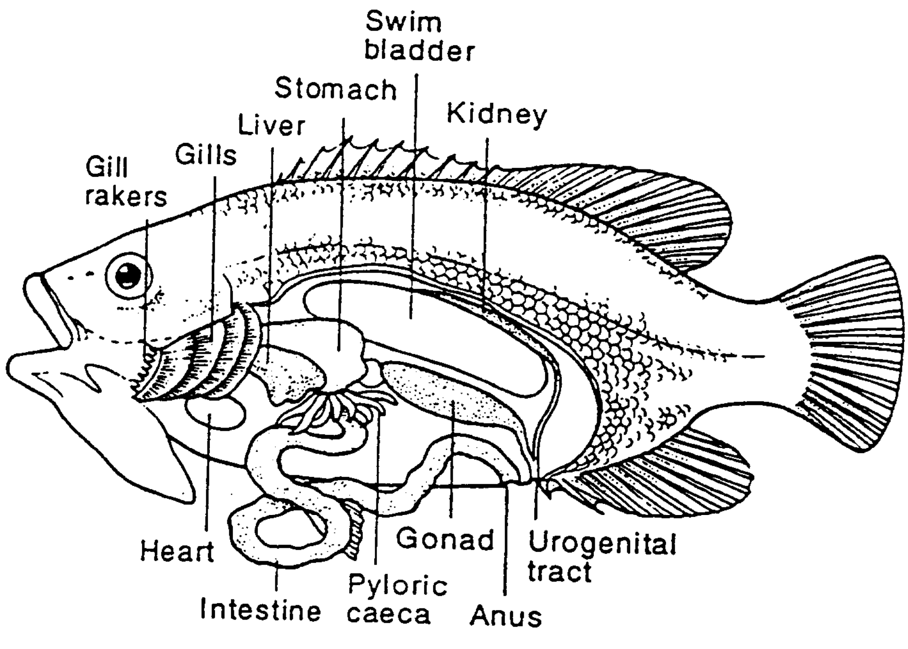
a) Observe, draw and label the external features of a fish.



b) Use a scalpel to make a small slit alongside the anus. Use a fine pair of scissors open the fish along the ventral surface as far as the gills.

c) Peel back, or carefully cut away the uppermost stomach cavity wall.

d) Observe, draw and label the internal structures as shown below.



Fish feed on a wide range of marine plants and animals.

- Herbivorous fish have a long intestine as plants are hard to digest.
- Carnivorous fish have a shorter intestine, and the size of food taken can be judged from the spacing of the gill rakers.

Female fish have ovaries which are usually paired, and occupy a large part of the body cavity when fully developed. In most fish, eggs are fertilised externally by sperm from males. External fertilisation occurs in about 96% of all fish species. The fertilised eggs hatch to small larvae (often about 5 mm in length) which are often transparent, with prominent eyes and a large yolk sac. Most larvae are planktonic and drift with ocean currents. In many species, recently hatched fish larvae move to the surface by night to feed on phytoplankton, and when larger, feed on other zooplankton. After a period which varies from species to species, the larvae metamorphose, and benthic species settle on the sea floor (overhead/handout 34). The juveniles of many fish species grow in nursery areas, including reefs, banks, bays, and estuaries. In many sharks and rays fertilisation is internal, and part of the pelvic or anal fin of the male is adapted for the transfer of sperm to females. In viviparous females, the ovary itself, or an area of the duct, is adapted to contain the developing young.

Demersal fish (those that live near the sea-floor) have evolved a great variety of shapes. Some have large filmy pectoral fins to manoeuvre around coral heads and into caves, and some are adapted for burrowing in the substrate. Some bottom-living fish, such as the box fish have re-evolved a hard covering for protection, while others, such as scorpionfish have developed poisonous spines.

Large demersal fisheries are located on the continental shelves, where primary productivity is higher than in the open sea, and the depths are sufficiently shallow to be accessible to towed trawl nets. There are several large tropical trawl fisheries, including those in gulfs, such as the Gulf of Mexico, the Persian Gulf and the Gulf of Thailand, and on continental shelves, such as those of India and China.

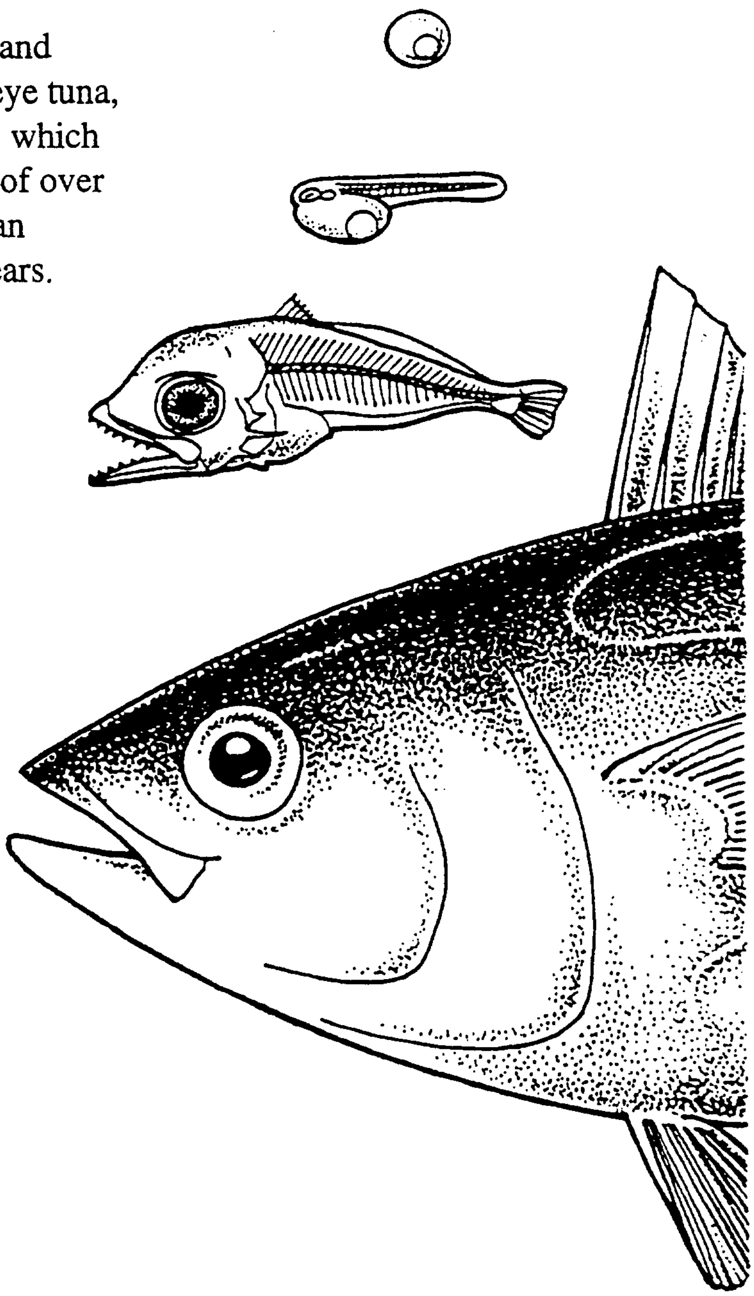
Inshore species in temperate waters are important in recreational fisheries, and some, particularly clupeids (sardines, herrings, sprats, pilchards) produce large catches used for canning and fishmeal. In tropical areas, inshore fish are more diverse, and include species of ponyfish, garfish, rabbitfish and tropical clupeids (overhead/handout 35). Such species provide an easily accessible source of protein for coastal villages. Several species of fish are adapted to take advantage of the inshore productivity. Mullets and ponyfish have mouths which are protractile, and ideally suited for feeding on bottom deposits and detritus. Goatfish have sensitive barbels which aid in locating food in the organic-rich substrates of inshore areas. Although some species of fish are permanent inhabitants of sheltered inshore areas, a much larger number of species use such highly productive waters as either spawning grounds, or nursery areas, or both. The mullet is typical of fishes which use estuaries and coastal areas for some part of their life-cycle. Large schools of mullet make spawning runs along coastlines, and sometimes move offshore as far as the edge of the continental shelf to spawn.

Coral reefs provide food and shelter for a greater variety of living things than most other natural areas in the world. Although there is a large number of different fish species (a high diversity) on coral reefs, the numbers of individuals within each species is relatively low (a low abundance of each species). Catches of emperors, groupers and snappers are particularly important (overhead/handout 36). Many species are sequential hermaphrodites, either changing from males to females such as some parrotfish, or changing from females to males as some wrasses and emperors. Several species show degrees of parental care for the eggs and even the young, but most species produce pelagic larvae. After metamorphosis, many coral reef fish become established in a particular home position on the reef and remain there throughout their adult life.

OVERHEAD/HANDOUT 34
LARVAL DEVELOPMENT OF FISH

- External fertilisation occurs in about 96% of all fish species.
- Fertilised eggs hatch to small larvae (about 5 mm in length) which are often transparent, each with prominent eyes and a large yolk sac.
- Most larvae are planktonic and drift with ocean currents.
- Larvae metamorphose to juveniles which adopt adult habitats.

The egg, larvae, and adult of the big-eye tuna, *Thunnus obesus,* which reaches a length of over 1.8 m in a lifespan of about eight years.



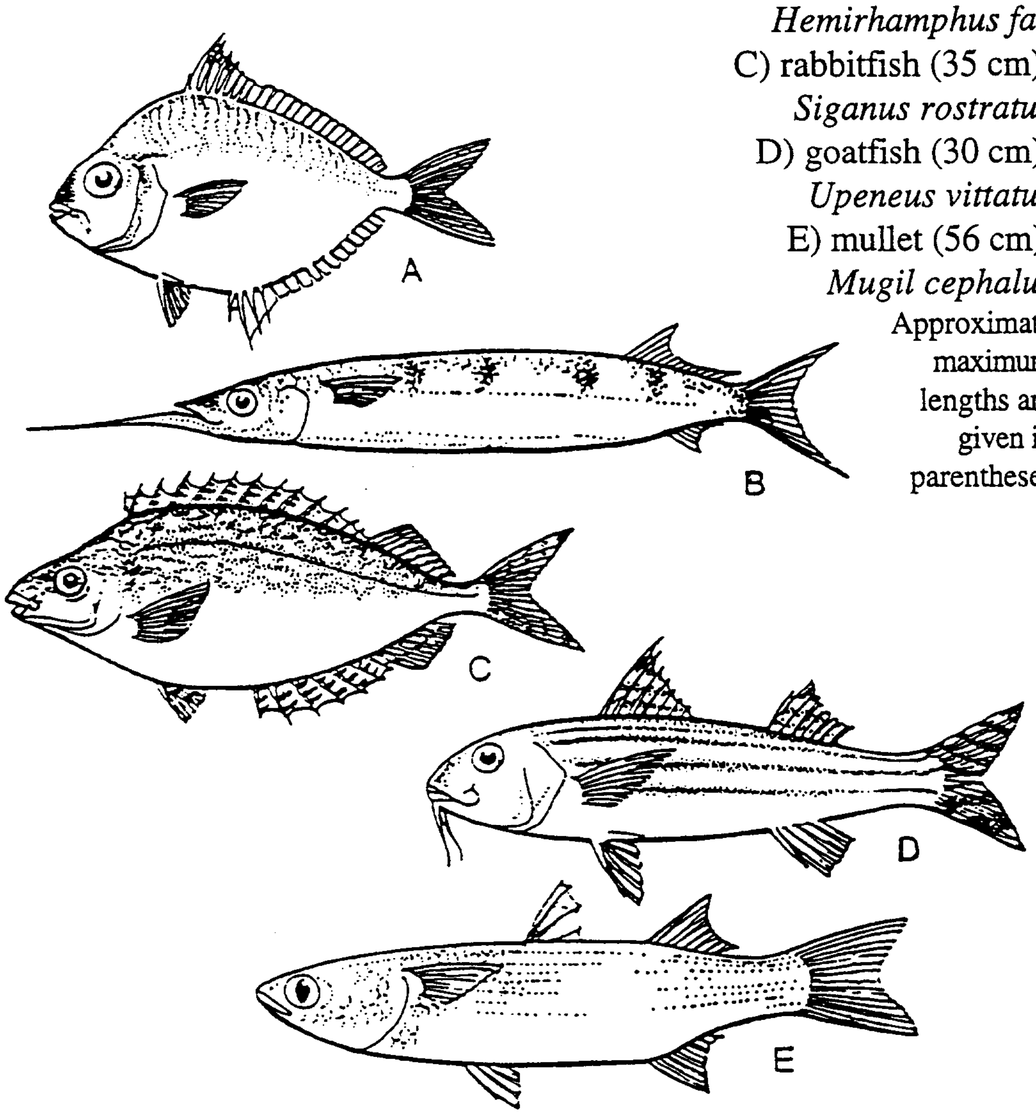
OVERHEAD/HANDOUT 35

FISH OF TROPICAL INSHORE AREAS

Sheltered inshore areas, particularly estuaries, are rich in food material and are therefore able to support a wide variety of fish species.
Estuarine fish may either,

- be permanent residents (eg. some goatfish),
- live in estuaries as juveniles (eg. some snappers),
- move into estuaries to breed (eg. some garfish), or,
- visit estuaries to feed (eg. some mullets).

A) ponyfish (13 cm), *Leiognathus splendens.*
B) garfish (50 cm), *Hemirhamphus far.*
C) rabbitfish (35 cm), *Siganus rostratus.*
D) goatfish (30 cm), *Upeneus vittatus.*
E) mullet (56 cm), *Mugil cephalus.*
Approximate maximum lengths are given in parentheses.



Deep water snappers (*Etelis, Pristipomoides,* and *Aphareus* species - overhead/handout 36). are caught in depths of about 200 m on the steep slopes beyond reefs and on seamounts in tropical countries around the world. These large value species are particularly valuable in tropical areas, as their distance from coral reef ecosystems means that they are unlikely to be affected by ciguatera (see overhead/handout 17).

Pelagic fish (those that live in the water column, or at the surface) rely on speed to catch their prey, and to avoid their own predators. As water is 800 times as dense as air, any part of the body which creates friction or turbulence causes a large amount of drag. Fast fish have bodies which are fusiform or spindle-shaped, as it is this shape which offers the least resistance when moving through the water. The caudal fin, which provides the propulsion, may be shaped like a scythe, with both a long leading edge, and a small surface area (a high aspect ratio). In many fast fish, the pectoral fins are used as brakes and rudders, and fit into depressions in the body when the fish is swimming at speed.

Clupeids (sardines, herrings, sprats, pilchards) and engraulids (anchovies) are pelagic fish typical of upwelling areas, and account for about 27% by weight of the total world catch. Although some of the catch is eaten fresh, canned and pickled, most is ground into fish meal, a protein additive used in agriculture for poultry and pigs. Large carangids, the jacks or trevallies, include *Caranx* species, which form hunting schools off many tropical coasts. The horse-mackerels or scads *(Decapterus, Trachurus, Salar)* are also found mainly in tropical and warm temperate seas. Scads occur in great abundance, and are often used for reduction to fish meal, although some species are important food fishes in tropical areas (overhead/handout 37).

Scombrids (tuna and mackerel) are found in tropical and warm temperate seas worldwide. The Indian mackerel, *Rastrelliger kanagurta,* is confined to tropical waters, and is commonly caught on coasts of the Indian and western Pacific Oceans. Another group of scombrids is the Spanish mackerels, which includes many species of *Scomberomorus,* and the large wahoo (or seerfish), *Acanthocybium solandri*, which can attain weights of 40kg. Spanish mackerels and barracudas *(Sphyraena)* are common and voracious predators in the vicinity of coral reefs. The best known open sea fish are the several species of tuna, which account for over 5% of the world catch. Tuna have been discussed previously in relation to oceanic food webs (see overhead/handout 6).

OBJECTIVES

The student will be able to a) recognise different types of inshore, demersal and pelagic fish, b) understand basic fish biology, and c) appreciate their relative importance in fisheries.

METHODS

Overhead/handout 33 should be used to show the external and internal features of fish, and overhead/handout 34 used to show larval development. Other overhead/handouts show the range and characteristics of fish.

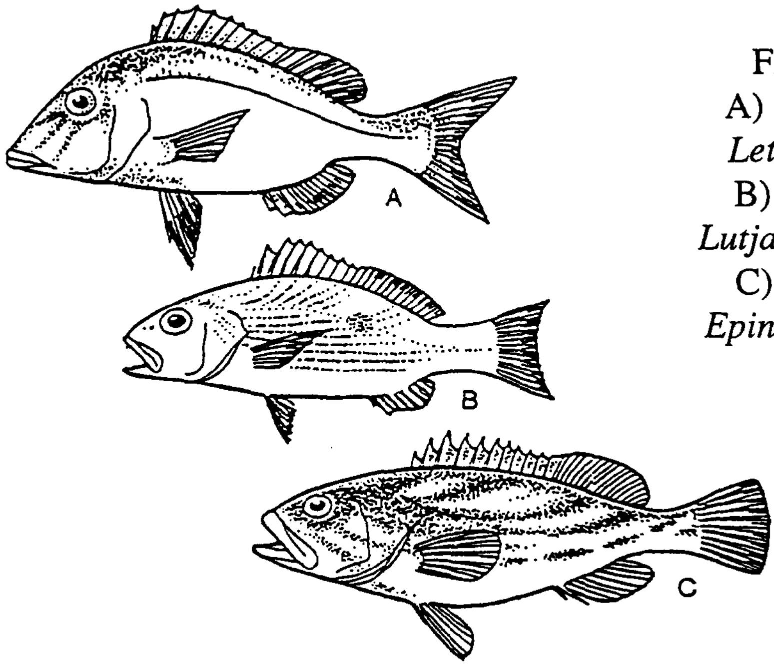
ACTIVITIES/ASSESSMENT

Biology students should be provided with a fish, and asked to draw the external features, dissect it, and draw its internal organs (see overhead/handout 33). A trip to a local fish market should be arranged, and students asked to list fish caught by local fishers.

OVERHEAD/HANDOUT 36

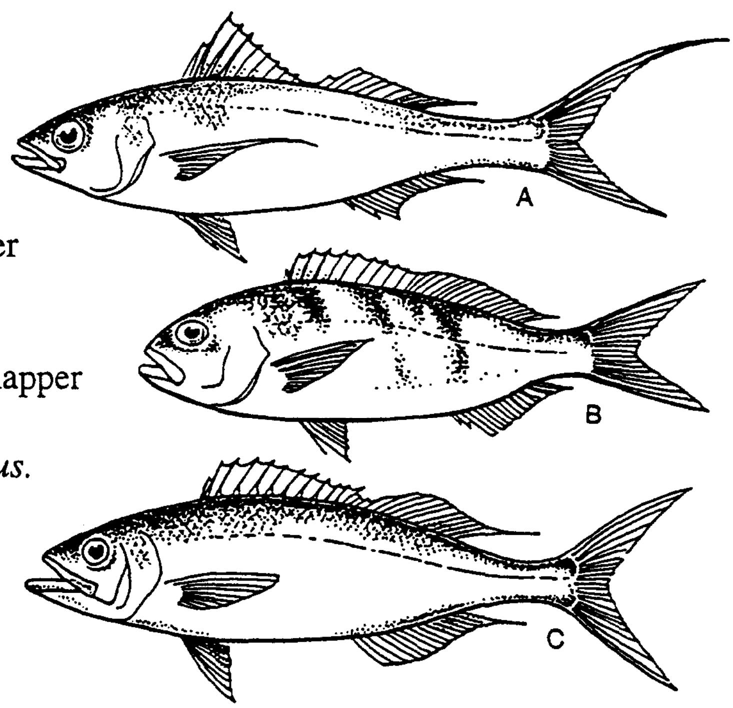
CORAL REEF and tropical DEMERSAL FISH

Coral reefs provide food and shelter for a greater variety of living things than most other natural areas in the world.



Fish of coral reefs; A) emperor (75 cm), *Lethrinus nebulosus.* B) snapper (35 cm), *Lutjanus fulviflammus.* C) grouper (60 cm), *Epinephalus morrhua.* Approximate maximum lengths are given in parentheses.

Demersal fish (those that live near the sea-floor) include the deep water snappers are caught in depths of about 200 m on the steep slopes beyond reefs and on seamounts in tropical countries around the world.

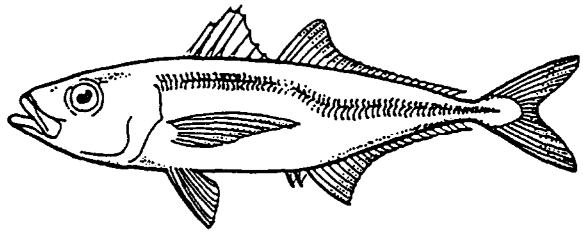


A) Long-tailed snapper (70 cm) *Etelis coruscans.* B) Oblique-banded snapper (50 cm), *Pristipomoides zonatus.* C) Rusty jobfish (80 cm). *Aphareus rutilans.*

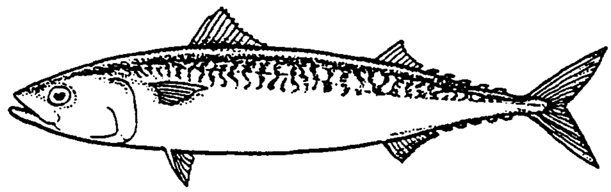
OVERHEAD/HANDOUT 37

PELAGIC FISH

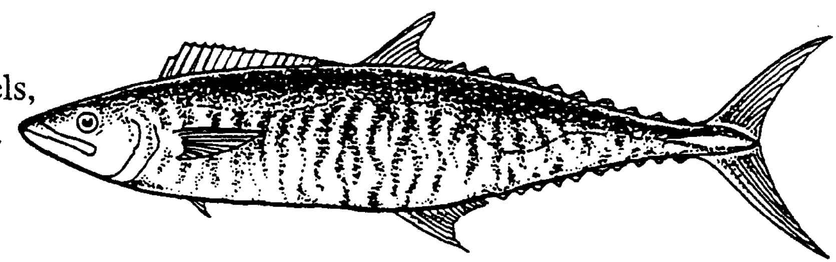
Atlantic scad,
Trachurus trachurus.
(39 cm)



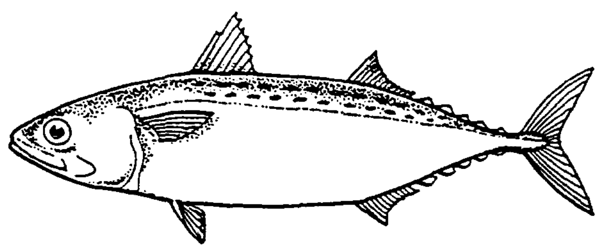
North Atlantic mackerel,
Scomber scombrus.
(45 cm)



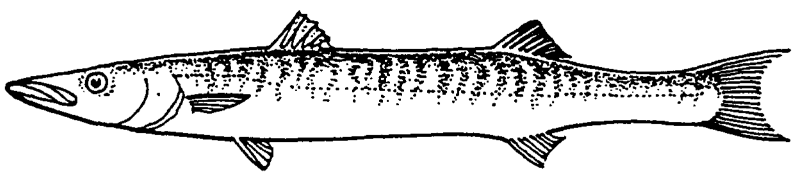
Spanish mackerels,
Scomberomorus.
(170 cm)



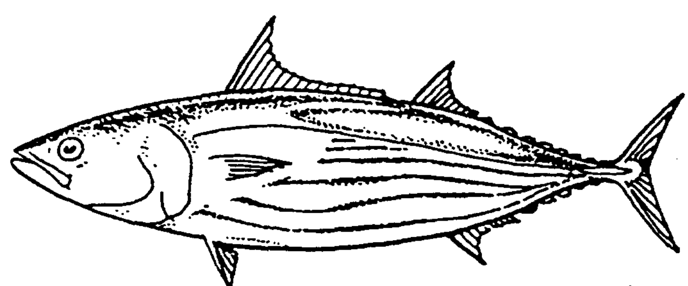
Indian mackerel,
Rastrelliger kanagurta.
(45 cm)



Barracudas
Sphyraena.
(100 cm)



Skipjack tuna,
Katsuwonus pelamis.
(100 cm)



38-41. FISHING METHODS

BACKGROUND

Fishing gear and methods used depend on the species fished. Techniques vary from very simple techniques, such as the hand collection, or gleaning, of shore-line invertebrates, to complex and expensive operations such as purse seining for tuna. Some of the fishing gear and techniques described in this section, such as traps and gill nets, are regarded as passive. That is, the gear remains stationary, and relies on fish moving to the gear. Fishing gear regarded as active, such as seine nets and trawl nets, are designed to be dragged or towed in order to catch fish. The distinction between the two types is important from a consideration of fishing costs and ecological acceptability. Because they do not require towing, passive gears are relatively inexpensive to operate, and have less potential to do damage to the sea floor. However, active fishing gear, particularly trawl and seine nets, account for a major part of the world's catch.

Baited traps

The principle of baited traps is that animals, attracted to the bait, enter the trap through tapered openings from which it is difficult to escape. Baited traps or pots are used to catch various carnivorous species of crustaceans, molluscs and fish (overhead/handout 38). The shape of traps, and the design of their entrances vary greatly. The number and position of the openings, and the size of meshes used in constructing traps are often controlled by fisheries regulations. In addition, traps used in some fisheries are required to have an escape gap, or an opening of a prescribed size, through which small individuals can escape.

Barrier and fence traps

The simplest traditional traps use the ebbing tide to strand fish in areas hollowed out on reefs and sandbanks, and contained by v-shaped or semi-circular walls of stone or coral. Fence traps include a wall built at right-angles from shore-lines and reefs to guide migrating coastal fish such as mullet into a large retaining area (overhead/handout 38). Fish may be either isolated in the retaining area by the retreating tide, or prevented from escaping by a complicated design or maze. Although originally made from stone or coral blocks, such traps are now usually made from modern materials such as wire-mesh netting. Their ease of construction, and the demand for their use by increasing populations, have resulted in authorities limiting the number of fence traps in some areas.

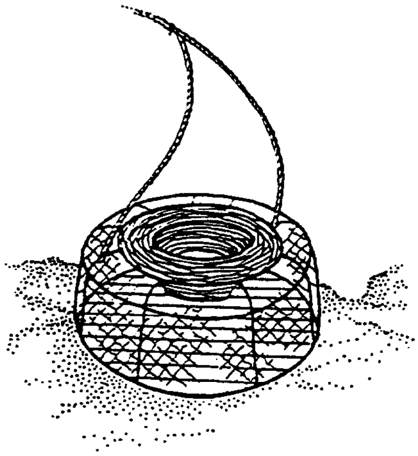
Hooks and lines

The most familiar type of manufactured steel hook is J-shaped (overhead/handout 38). Circle hooks are similar in design to the bone or shell hooks which have been used since prehistoric times by many coastal peoples. When a fish strikes a circle hook, the point rotates around the jawbone, ensuring that the fish remains caught without the fisher having to maintain pressure on the line. Steel circle hooks are now used to catch tuna, sharks, halibut and deepwater snappers. Handlining gear consists simply of one or more baited hooks attached to a line, which is weighted at the bottom in the case of demersal target species. When handlines (or droplines) are used to catch demersal fish in deep water, mechanical means may be used to haul in the line. Many small artisanal vessels used to catch deepwater snappers in tropical areas use simple wooden hand reels to retrieve lines from depths of about 200m (overhead/handout 39).

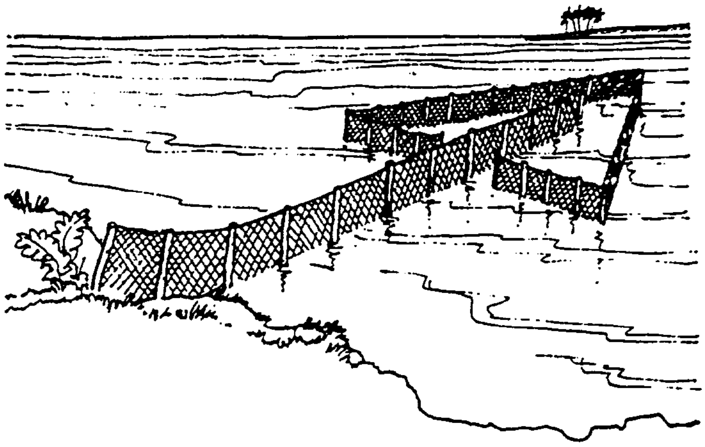
OVERHEAD/HANDOUT 38

FISHING METHODS - traps and hooks

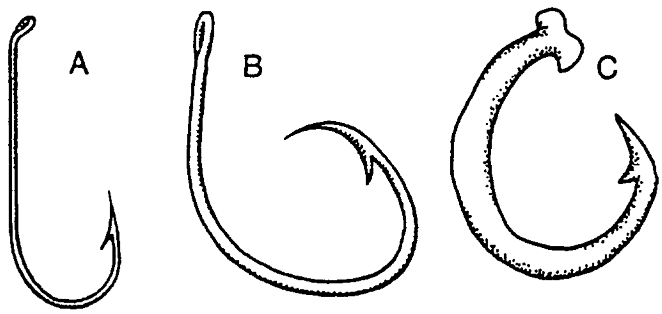
A crustacean pot or trap.



A fence trap used to catch migrating coastal fish.



Fish hooks:
A) a common J-shaped hook,
B) a modern circle hook, and
C) a Pacific Island traditional bone hook.



A longline consists of a mainline with hooks set on short side-lines or snoods. A horizontal longline may be set near the surface for pelagic fish such as tuna, or on the sea-floor for demersal species such as sharks. Long-lines set in the open sea for tuna may be 100 km long and fish down to depths of 400 m (overhead/handout 39). A vertical longline, with hooks set from snoods along its lower section, is set perpendicularly in the water column in areas where the sea floor is steep or rugged.

Natural or artificial lures attached to lines may be towed (or trolled) behind boats to catch pelagic species, such as mackerel, dolphinfish and tuna. In general, lures are designed to attract fish by having an erratic movement when towed through the water (to resemble an injured prey) and a bright or reflective surface. Instead of artificial lures, small silver fish such as garfish and flying fish, or pieces of larger fish, may be threaded onto one or a series of hooks (overhead/handout 39).

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

Squid are also caught commercially on barbless lures, or jigs (overhead/handout 39) attached either to handlines, or to automatic jigging machines. The machine automatically lowers the line to a set depth, and an elliptical drum retrieves the line with a jerking or jigging movement. During night fishing, bright lights are used to attract squid into the fishing area.

Stationary nets

Gill nets and trammel nets are panels of netting held vertically in the water column by a series of floats attach to their upper edge (the floatline, or corkline), and weights attached to their lower edge (the footrope, or leadline). These nets may be either anchored in shallow water, or set to drift in the open ocean. As passive gear, their catching ability relies on the movement or migration of fish through the area where the nets are set (overhead/handout 40).

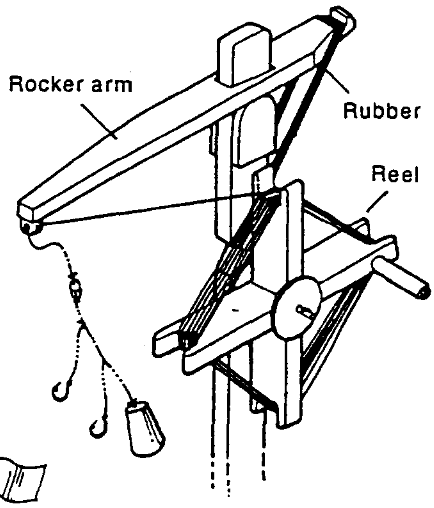
Gill nets are used in shallow water to catch species such as mullet and mackerel. In deeper water they may be set on the sea-floor for demersal species such as sharks, or near the surface for pelagic fish such as tuna. The nets are often made from almost invisible monofilament nylon strands, which lock behind the gill covers (opercula) of bony fish or the gill slits of sharks. There have been concerns regarding the use of very long gill nets, or drift-nets, left in the open sea. Drift nets may be 50 km in length and catch non-target species including dolphins. Due to international concern and political pressure, the number of vessels using drift nets has been dramatically reduced over recent years.

A trammel net or tangle net is constructed from a panel of small mesh net sandwiched loosely between panels of larger mesh net. The nets are set in the same way as gill nets, but catch a much larger size range of fish by entangling rather than gilling them. Fish coming into contact with the middle panel of small mesh netting, are prevented from breaking free by the outer panels of larger mesh netting. Fears have been expressed regarding "ghost fishing" by lost gill nets and trammel nets. As the nets are made of synthetic rot-proof material, a net or section of net which is lost will continue fishing for many years.

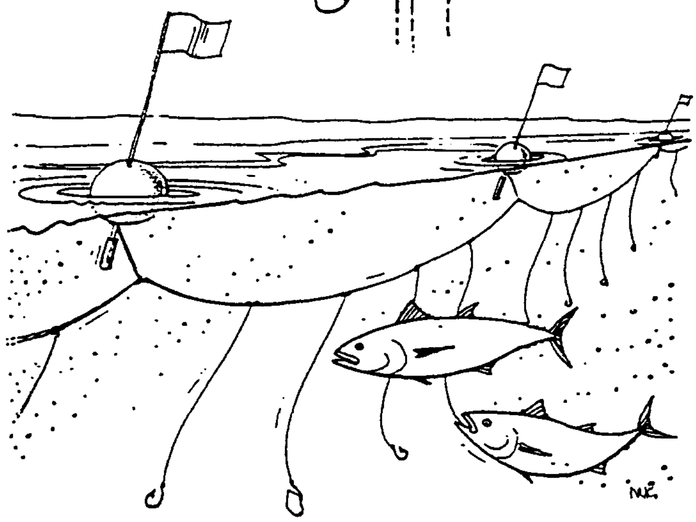
OVERHEAD/HANDOUT 39

FISHING METHODS - line fishing

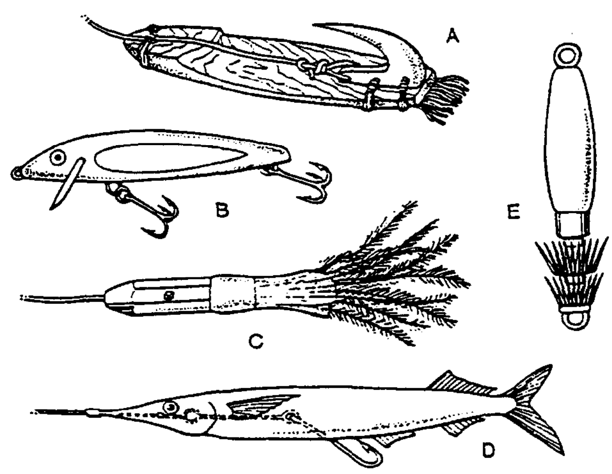
A hand-reel used to retrieve droplines set to catch deepwater snappers in depths of about 200m.



A tuna long-line.



Fish lures:
A) traditional shell lure.
B) "hard" fish lure.
C) "soft" fish lure.
D) baited lure.
E) squid jig.



Towed nets

Some nets such as trawls are designed to be towed through the water to sieve out fish and marine invertebrates. These are the most widely used methods of catching fish in the world, and there are many variations in design and towing methods. An otter trawl consists of a conical or funnel-shaped net leading into a bag, or codend, in which the fish are retained (overhead/handout 40). Otter trawls derive their name from the otterboards, or doors, which act as paravanes to hold open the mouth of the net when towed. Beam trawls are similar in design to otter trawls, but the net is spread open laterally by a horizontal beam instead of otter boards.

Surrounding nets

Surrounding nets are designed to be dragged or towed in an arc around fish. The schooling behaviour of coastal and oceanic pelagic fish make them particularly vulnerable to such gear.

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

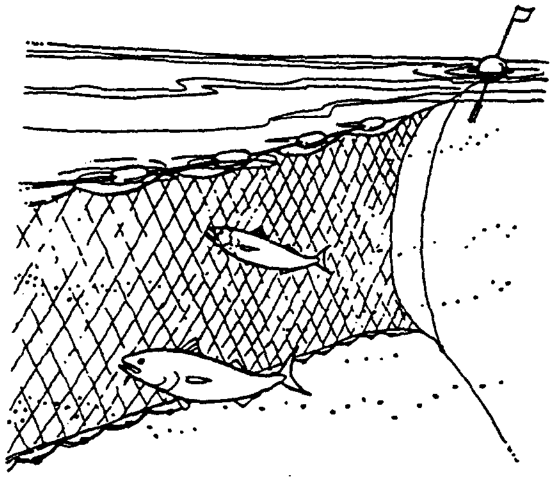
A purse seine is a net which is set in a circle around a school of pelagic fish such as tuna, mackerel and pilchards. In terms of total catch weight from a single operation, a purse seine is one of the most efficient types of fishing gear in the world, and over 100 tonnes of fish may be captured in a single shot of the net. The net is essentially a long panel of netting (up to 2 km in length) with floats fastened to its upper edge and weights and purse rings attached to its lower edge. Once a school is located, sometimes with the aid of sonar and a ship-based helicopter, the end of the net is attached to a buoy or a skiff, which is cast off (overhead/handout 40). The vessel releases more and more of the net as it moves around in a large circle, which is completed when the two ends of the net are brought together. After the net ends are retrieved, the purse wire, which runs through the rings around the lower weighted edge of the net, is hauled in to close off the bottom of the net, and prevent fish from escaping downwards.

Fish aggregation devices (FADs):

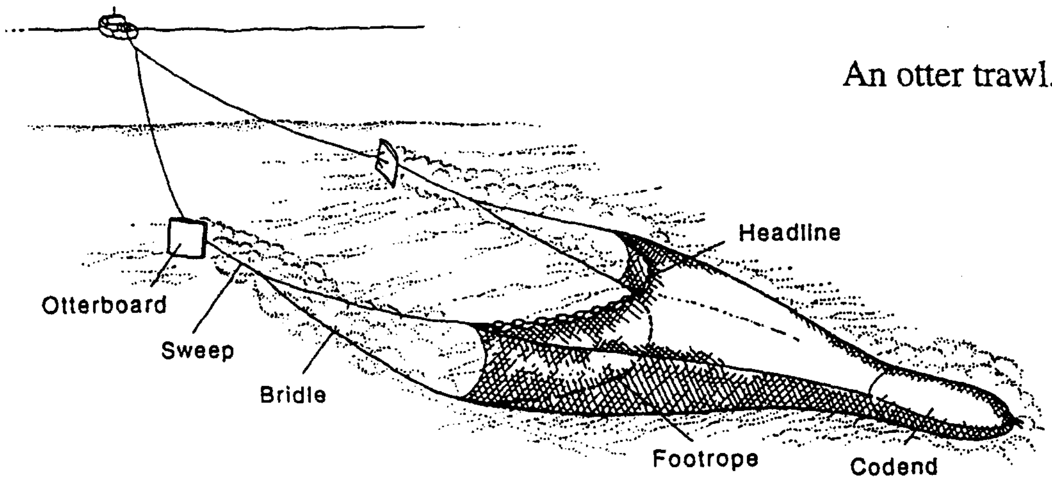
Many species of fish that inhabit the open sea are attracted to floating objects; some tunas, for example, congregate around drifting logs. This behaviour has been used in the deployment of fish aggregation devices (FADs), floating rafts anchored offshore in depths of over 1000 m to attract pelagic fish. A range of materials, including coconut logs, bamboo, and aluminium pontoons have been used in the construction of rafts. Material such as old fish nets, palm leaves, and car tyres are suspended beneath the rafts in the belief that this increases the raft's effectiveness as a habitat for fish. Modern deepwater mooring systems consist of a sinking (nylon) rope spliced to a buoyant (polypropylene) rope attached to an a chain and concrete block anchor (overhead/handout 41). This combination of ropes induces a mid-water S-bend, or an inverse catenary, which contains the slack line in the system and prevents chafing. The benefits of FADs are that they reduce the search time involved in a fishing trip, and therefore reduce fuel costs, as well as increase fish catches. However the costs of building and setting FADs are high, and, because of storms, wear and vandalism, their average life-span is less than 12 months.

OVERHEAD/HANDOUT 40
FISHING METHODS - nets

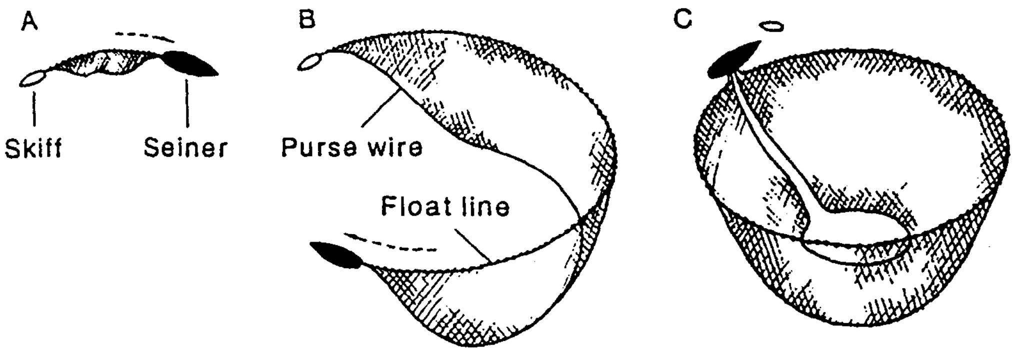
A gill net.



An otter trawl.



The sequence of operations in purse seining.
A) the end of the net is attached to a buoy or a skiff (outline shape).
B) the seiner (solid shape) releases net as it moves away in an arc;
C) the two ends of the net, and the purse wire at the lower edge of the net, are hauled in. Movement of the seiner is shown by dashed arrows.



Destructive effects of fishing

In the broadest sense, all fishing is environmentally damaging to a greater or lesser degree. Many fishing gears are unselective with respect to both size and species in the catch. Compared with gill nets, for example, trammel nets are unselective in that they catch a wide size range of individuals, and catch a much larger number of different species. For this reason, the use of trammel nets is banned in some areas. Much development in gear technology is aimed at reducing the catch of small individuals, and non-target (by-catch) species. In trawl nets, the use of square meshes (rather than the more conventional diamond-shaped ones) has been shown to reduce the capture of small individuals. Even when more selective fishing gear is used, food chains and predator-prey relationships are almost certainly affected by the removal of a particular target species from the environment.

Particular types of active fishing gear, such as trawl nets with heavy ground chains, are known to be highly destructive to the sea-floor and its marine life. In many fisheries, steps are being taken to replace destructive gears with those which are less environmentally damaging. New types of lighter trawling gear, for example, are being designed to skim the sea-floor rather than dig it up.

In some countries, 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. These destructive fishing methods include the use of toxic plants, commercially available poisons such as bleaches (Sodium hypochlorite), insecticides, and explosives. Poisonous plant material is traditionally used to catch fish in many tropical countries. Explosives and severe poisons 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 production, and may not recover for many years.

As population increases place greater demands on fisheries resources and the marine environment, the role of fisheries technologists will assume an even greater importance. The challenge will be to devise fishing gear and methods which do not threaten the environment or non-target species, yet catch the target species in the most economically efficient manner.

OBJECTIVES

The student will become familiar with a range of methods and gear used to catch marine species.

METHODS

The overhead/handouts should be used to show a range of methods and gear used to catch marine species. The effectiveness of the different gears, and the potential of different gears to cause overfishing and environmental damage should be emphasised.

ACTIVITIES/ASSESSMENT

A trip to a local fishing port should be arranged. Students should be asked to list the types of fishing gear used by local fishers, and to examine their potential to cause overfishing and environmental damage.

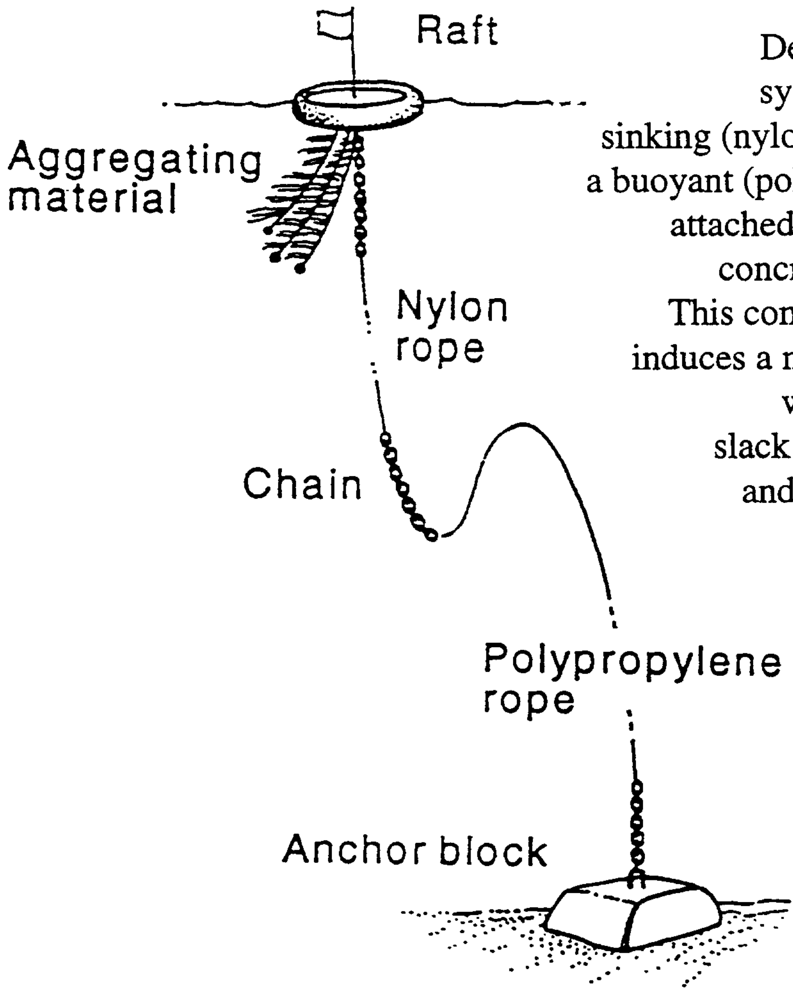
OVERHEAD/HANDOUT 41

FISHING METHODS - fish aggregation devices

Fish Aggregation Devices (FADs), are floating rafts anchored offshore, sometimes in depths of over 1000 m, to attract pelagic fish. Many pelagic fish are attracted to floating objects.

A range of materials, including coconut logs, bamboo, and aluminium pontoons have been used in the construction of rafts.

Material such as old fish nets, palm leaves, and car tyres are suspended beneath the rafts in the belief that this increases the raft's effectiveness as a habitat for fish.



Deepwater mooring systems consist of a sinking (nylon) rope spliced to a buoyant (polypropylene) rope attached to an a chain and concrete block anchor. This combination of ropes induces a mid-water S-bend, which contains the slack line in the system and prevents chafing.

UNESCO-UNEP International Environmental Education Programme (IEEP)
The Oceans and Coastal Areas and their Resources. M.King and S.King.
UNEP

42-44. FISHERIES MANAGEMENT

BACKGROUND

Fisheries biologists contribute to fisheries science in two main areas; first, by studying the basic biology and distribution of resource species (which leads to the elucidation of the life-cycles described in previous sections), and second, by studying the population dynamics of the species. Population dynamics is the study of how fish populations or stocks change in weight and numbers in response to characteristics such as growth and death (mortality) rates.

In order to discuss population dynamics, it is instructive to consider a fish population or stock as a simple biological system. The forces acting on a fish stock, and controlling its numbers, are shown in the figure on overhead/handout 42. The number of fish is being increased by the reproduction of adult fish, which eventually results in small fish being added, or recruited, into the stock. In addition, the weight, or biomass, of the fish stock is increased by the growth of individuals - in the figure, three consecutive age groups, or year classes, are shown. At the same time, the stock is being reduced in numbers and biomass by natural mortality and, in exploited species, by fishing mortality as well. Fishing mortality refers to fish caught by fishers, and natural mortality refers to fish which die by other means, most commonly through predation.

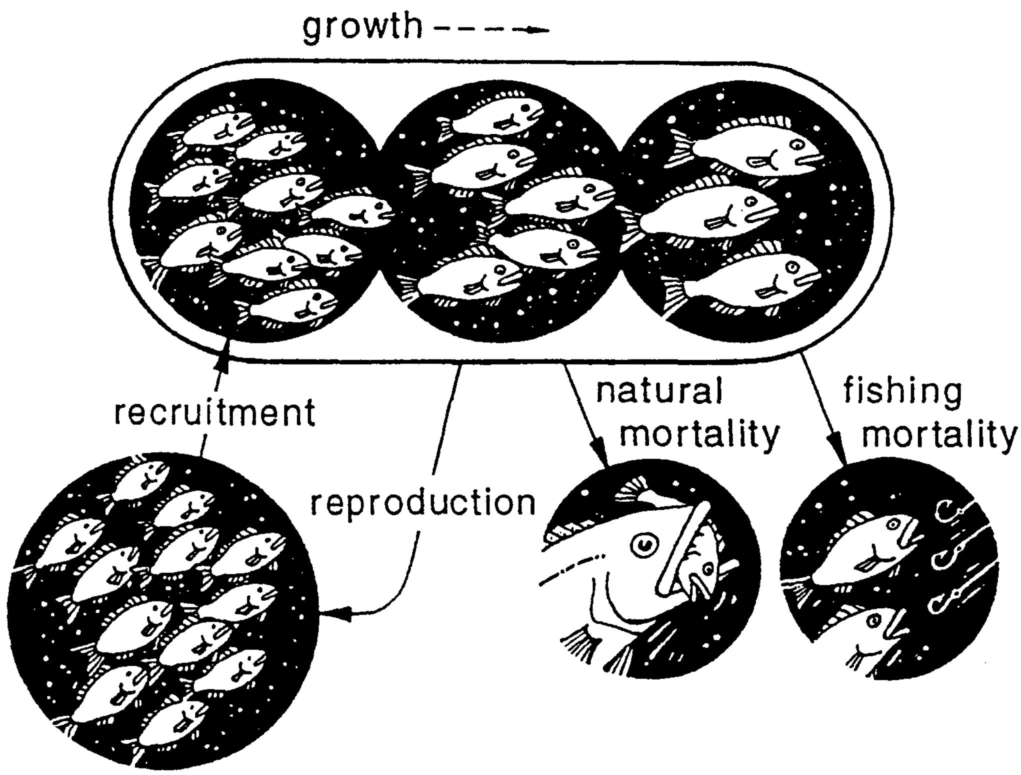
In a species which is unexploited, or fished at a low level, losses due to mortality are balanced, on the average, by gains through recruitment. Stock abundance will fluctuate around a mean level. If exploitation is high, the number of adult fish may be reduced to a level where reproduction is unable to replace the numbers lost. In terms of the figure on overhead/handout 42, if the number of fish caught becomes too large, recruitment will be too small to maintain the stock size, and the numbers of fish will decrease.

The stock sizes of many exploited species are at dangerously low levels. The Antarctic baleen whale, the Peruvian anchovy, the North Sea herring and mackerel, and the Australian southern school shark have all been dramatically overexploited. In severe cases of overfishing, a particularly vulnerable species may even become extinct. Some species of giant clams, for example, have now disappeared from several countries.

A major task of a fisheries biologist is to estimate the population parameters implied in the figure on overhead/handout 42, namely stock abundance, growth, recruitment and mortality. The system is dynamic, however, and values of these parameters may fluctuate widely, even in the absence of fishing. The estimation of population parameters, such as growth and mortality, is beyond the scope of this book, but is undertaken by fisheries scientists in order to estimate the yield, or catch, that can be taken from a fish stock year after year without harming, or overexploiting, the stock. A fish stock may be regarded as overexploited when the numbers of fish are reduced to such an extent that the remaining adults are unable to produce enough young fish to maintain the stock.

The renewability of fisheries resources depends on accepting controls which not only protect fish stocks, but ensure that the environment in which they live does not deteriorate. This implies that fisheries have to be managed, and that regulations have to applied to control either the amount of fishing or the amount of fish caught. The main problem is not in enforcing fisheries regulations, but in convincing the community that they are necessary.

OVERHEAD/HANDOUT 42
A FISH STOCK AS A BIOLOGICAL SYSTEM



The numbers in a fish stock (top elongate shape) are being increased by reproduction, which results in the addition (or recruitment) of small fish to the stock.

The weight (or biomass) of the fish stock is being increased by growth (three age groups are shown).

At the same time, the stock is being reduced by natural mortality, and, in exploited species, by fishing mortality.

Fishing mortality refers to fish caught by fishers, and natural mortality refers to fish which die by other means, most commonly by predation.

The view that the sea represents an inexhaustible food larder has persisted in some popular texts until quite recently, even though many of the major fish stocks of the northern Atlantic had shown signs of reduction by the end of the nineteenth century. The recognition that all fisheries resources are finite has set the scene for the conventional model of fisheries development illustrated on overhead/handout 43.

In the early stages of development in a fishery, each increase in the amount of fishing (say the number of boats) produces a corresponding increase in the annual catch or yield. At this stage, catch rates (catch per hour fished) will be high, encouraging the entry of more fishing boats into the fishery. As the amount of fishing continues to grow, the resulting increases in yield will not be as great, and mean catch rates will decrease. Eventually the addition of further boats will no longer produce an increase in yield. This is the amount of fishing that is required to secure the Maximum Sustainable Yield (MSY), which represents the mean maximum catch that can be taken from the fishery without affecting the biology of the stock (or the balance of the system shown on overhead/handout 42). If fishing effort is increased beyond that necessary to obtain the MSY, the adult stock may be reduced to the extent that insufficient young fish are produced to maintain the stock. The biological effect of continuing excessive fishing is that fish yields will continue to decrease, on the average, year after year.

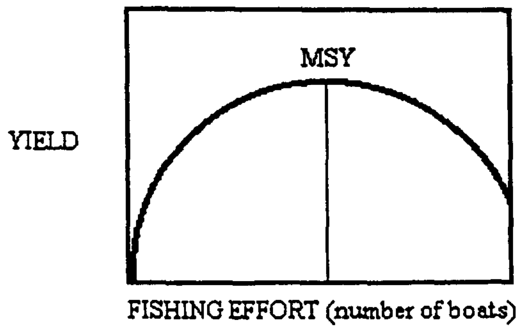
In an economic sense, excess fishing occurs when the cost of fishing exceeds the value of the catch. Assuming that the cost of fishing is directly proportional to the amount of fishing, total fishing costs will increase linearly as the number of boats increases. If the price of fish is constant, the total revenue curve will have the same shape as the yield curve in terms of weight. Total profit from the fishery is maximised where the distance between the revenue curve and the cost line is the greatest. This point is referred to as the Maximum Economic Yield (MEY) from the fishery. In a fishery where there is no control on the amount of fishing (an open access fishery), more people will be attracted into the fishery by high profit levels until, at the economic breakeven point, total costs will equal total catch value and no profits are made.

If a fish stock is regarded as a common property resource, fish may be regarded as belonging to the community. A farmer, who manages his stock (a private property resource) will get the benefits of sensible management. However, if a fisher decides not to catch small fish, for instance, in the hope that they will grow to a more marketable size, other fishers may catch them before he does. In other words a sensible management decision taken by an individual fisher may not result in any personal benefit. There is no incentive in open access fisheries for individual fishers to restrict their effort as long as costs remain less than revenue. Each individual in the fishery is motivated to compete for a maximum share of the resource, and has little incentive to practise conservation. If demand remains high in relation to fishing costs in an unmanaged fishery, it is almost inevitable that the amount of fishing will continue to increase, and the stock will become overexploited in both an economic and biological sense.

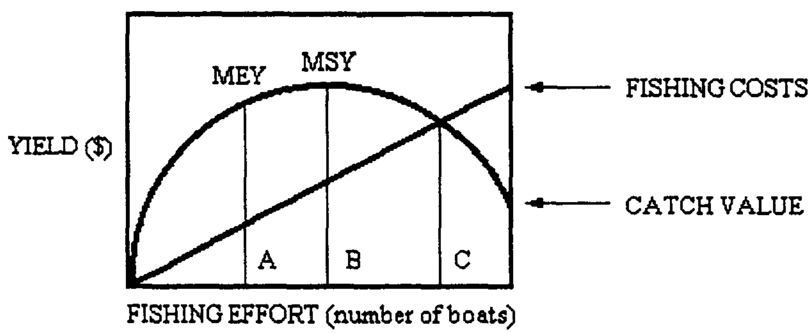
Historically, the main objective of fisheries management has been the conservation of fish stocks. In modern fisheries management, the broad objectives may include the conservation of fisheries resources and their environment, the maximisation of economic returns from the fishery, and payment of fees to the community from profits made by the exploitation of a public resource. Subsuming all these objectives is the need to ensure that fisheries are exploited on an ecologically sustainable basis.

OVERHEAD/HANDOUT 43

SUSTAINABLE YIELD FROM FISHERIES



- In the early stages of a fishery, each increase in the amount of fishing (say the number of boats) will produce an increase in the annual catch (or yield).
- Eventually, a point will be reached when any further increase in the amount of fishing (or fishing effort) will no longer result in an increased yield.
- This point, called the Maximum Sustainable Yield (MSY), represents the maximum yield that can be taken from the fishery without affecting the biology of the stock.



- The total cost of fishing (the straight line) increases with each additional boat in the fishery.
- The total profit (or rent) from the fishery is maximised where the distance between the cost line and the catch value curve is greatest; this is referred to as the Maximum Economic Yield (MEY).
- If there is no control on the amount of fishing, more boats will be attracted into the fishery by the high profits (at point A) until total costs equal total catch value (at point C) and no profits are made.

The renewability of fisheries resources depends on devising regulations, and having them accepted by the community, in order to protect fish stocks and the marine environment. The fisheries regulations described below are used either to reduce or contain the amount of fishing or to control the amount of fish caught.

QUOTAS: A quota is a limit to the amount of fish which can be caught in a particular year or a fishing season. Once this quota, or maximum catch, has been reached, the fishery is closed. Alternatively, each fisher may be allocated an individual quota.

LIMITED ENTRY - Entry into a fishery may be limited to a certain number of people or boats; for example, a limited number of licences may be issued which permit people to fish. The alternative is a fishery in which anyone can go fishing (an open entry fishery).

LIMITING THE CATCH OF SMALL INDIVIDUALS - Preventing the capture of small fish may allow them to grow to a more valuable market size; in some cases it may also allow individuals to reach a size where they can reproduce before capture. The capture of small fish may be prevented by mechanisms such as enforcing the use of nets with a large mesh size. Where fish are not harmed by the catching method, in trap fishing for example, fishers can be forced to return small individuals to the sea.

CONTROLS ON FISHING GEAR & METHODS - Highly destructive methods of fishing, such as the use of chemical bleaches or explosives, are illegal in most countries. Highly efficient fishing methods may also be controlled to allow more people to share the resource. Controls may include banning or reducing the efficiency of particular fishing methods or fishing gears. For example, gill nets may be restricted to a certain length, and the use of scuba diving to catch lobsters may be prohibited.

CLOSED SEASONS AND AREAS - Fishing may be banned either at particular times of the year, or in particular places. Closures during particular seasons, for example, may allow small individuals to grow to a more marketable size, or may allow adults to breed without interference. Closed areas may include nursery areas, such as mangrove habitats.

OBJECTIVES

The student will be able to a) view a fisheries resource as a biological system which can be disrupted by overfishing, b) appreciate the need to manage fisheries, conserve fish stocks, and protect the environment, and c) appreciate the need for fisheries regulations.

METHODS

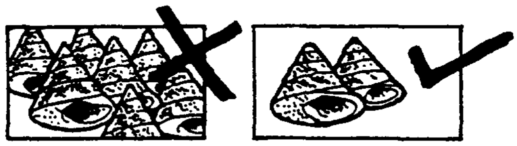
Overhead/handout 42 should be used to show a fisheries resource as a biological system. Local examples of fish stocks which have been affected by overfishing or environmental damage should be given. Overhead/handout 43 should be used to convey the concept of overfishing, and overhead/handout 44 should be used to discuss fisheries regulations.

ACTIVITIES

A visit to a Fisheries Research Station or Department may be arranged, so that officers can explain the research undertaken, and management and regulations applied to local fisheries. Projects could include an investigation of particular fish stocks which have been affected by overfishing or damage to the marine environment. Students could prepare a summary of regulations (and their purpose) which have been applied to local fisheries.

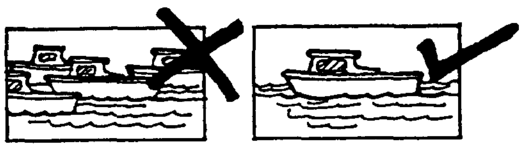
OVERHEAD/HANDOUT 44

FISHERIES REGULATIONS



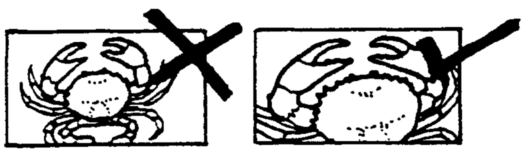
QUOTAS

Catches from a fishery may be limited to a certain amount called a quota. Once this quota has been reached the fishery is closed.



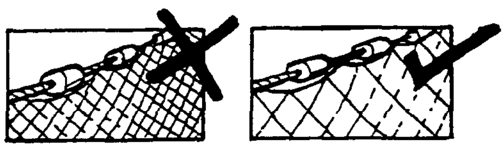
LIMITED ENTRY

As an alternative to allowing anyone into a fishery (an open entry fishery), entry may be limited to licensed fishers (a limited entry fishery).



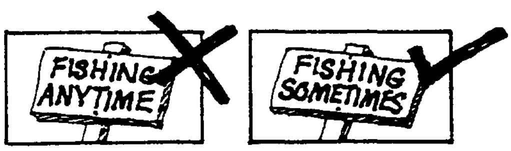
SIZE LIMITS

The capture of small fish is either prevented (by using large mesh nets, for example) or fishers must return small fish to the sea.



CONTROLS ON FISHING METHODS

The use of environmentally destructive, or highly efficient fishing methods may be restricted in the interests of protecting the environment or conserving fish stocks.



CLOSED SEASONS AND AREAS.

Fishing may be banned during specific times of the year, or in particular areas, to protect small individuals or reproducing adults.

MARINE EDUCATION

It is inevitable, and highly desirable, that some high school students studying the subjects outlined in this book will be encouraged to pursue a career in an area related to the marine environment. However, a more important aim is to produce future citizens who are more environmentally aware and responsible.

It is education that gives people the knowledge and skills to make informed decisions, and the ability to act on them. Such people will recognise the importance of the marine environment, have an awareness of environmental issues, and be able to discuss technical and social solutions to problems. Managing and protecting the marine environment and its resources will only be possible when communities, rather than governments and scientists, take part in expressing environmental concerns and in suggesting solutions.

But, of course, professionals are needed to provide technical advice and training to communities. Formal education, beyond high school level, provides the scientists, planners, engineers and technicians needed to manage and protect the marine environment. Some careers involve lengthy academic studies, while others involve a shorter time of practical training. For any professional career, a Degree in a tertiary institution is generally the minimum requirement. The selection of a course and an Institution depends on a student's interests, and the area in which employment will eventually be sought. Most employment opportunities connected with topics covered in this book are in government departments responsible for fisheries or the environment, and in tertiary educational institutions.

Students interested in biology may continue their studies in marine ecology. Some may find employment with environmental authorities, and play a part in protecting coastal ecosystems. Others may work in fisheries departments or fisheries research institutions, studying the biology of commercially important species and suggesting policies for fisheries management and development. Students continuing with studies in sociology may eventually work with coastal communities, and seek to involve them in caring for and managing the marine environment. Students with interests in mathematics and statistics and computing may find employment involving the collection and analysis of data such as fish catches and the amount of fishing. Computer programmers maintain computer databases that collate, analyse and summarise economic and biological information for development and management. Those interested in economics can go on to study resource economics, and work to collect and analyse economic information for coastal and fisheries development and management. Students interested in physics may go on to study engineering, and may work on hydrology and the protection of coastlines. Chemistry students may complete studies in bacteriology and biochemistry, and find employment in areas ranging from seafood processing to the treatment of sewage. For students who are less academically inclined, practical training in skills such as SCUBA diving and boat handling would equip them for positions including marine park guides and technical assistants.

In many cases it is possible for high school teachers to arrange for local professionals to visit the school and talk to students. A visit to an appropriate local research institution or government authority, with tours and talks conducted by professional emloyees is an even better option. In these ways, students can more readily understand the challenges, problems and tasks facing professionals in a range of careers.

SYLLABUS DEVELOPMENT

The introduction to this book suggested that a multidisciplinary approach, introducing aspects of environmental education into subjects that students are currently studying, may be the most convenient way to provide students with exposure to environmental topics in the short term. It was also suggested that, wherever possible, it is desirable to introduce a separate environmental education subject into high school curricula. This interdisciplinary (single subject) approach provides environmental education with discipline status, and even though input from other areas is required, is the most likely way to provide the subject with the legitimacy that it deserves. This section assumes that the more preferred interdisciplinary (single subject) approach is to be followed.

A first and necessary stage of environmental education is to provide students with a background knowledge of ecological concepts, which are based on biological, chemical and physical properties of the environment. A second stage is to provide an awareness of environmental issues and their relationship to ecological concepts. This requires mastery of much broader issues including sociology, economics and human behaviour, including personal, political and cultural activities and how these interrelate.

The curriculum design should extend goals beyond the knowledge level to include the development of critical thinking and problem solving skills. This requires extending the topics to introduce social perspectives, debate and problem solving. Problem solving should have a community focus.

Although a course such as one based on this book will provide some technical knowledge and an environmental awareness, solving environmental problems is a community issue. Students should be encouraged to discuss ways in which the community can be made more aware of environmental issues, and ways in which people can take part in defining their own environmental concerns and in suggesting solutions.

Several topics in this booklet are extended to deal with environmental investigations, evaluations and a discussion of remedial actions. The balance between the needs for development and protection of the marine environment, for example, is stressed in the section entitled "Coastal Development and Sources of Pollution". The teacher should, wherever possible, introduce exercises based on real problems and discuss possible solutions.

As an example of the various levels at which a subject may be presented, the student goals relating to the section on "Energy from the Oceans" in particular, Ocean Thermal Energy Conversion (OTEC) systems (see overhead/handout 4) are suggested below.

a) The student should be able to reproduce in diagrammatic form, a OTEC system.

b) The student should be able to understand how an OTEC system works including the physical principles involved.

c) The student should be able to compare the environmental impact of an OTEC installation in comparison to other energy generating systems.

d) The student should be able to debate the question "Why does society require so much electricity anyway?" - and discuss ways of reducing this requirement.

A syllabus should have three components, including and aim, a course outline and assessment schedule.

1) AIM:

This should clearly state the objectives of the course, that is, what must be learned by the students. Each of the topics in the course will have its own more limited aims, but these should contribute to the overall aims of the course.

It is useful to break down the aims of each topic to a series of goals from a restricted knowledge level to the more meaningful levels of community participation and problem solving (as suggested in the OTEC example on the previous page).

2) COURSE OUTLINE:

This should list in some detail the various components or topics of the course, including the activities and resources which will be used to achieve the aims of the course. Each of the topics in the course may have its own outline of sub-topics.

The contents page of this book may provide the basis of a course outline, and this could be adapted to suit local environments and concerns. However, it is desirable to include a broad and global overview of each topic in the presentation before concentrating on aspects which are of local importance. The degradation of coastal areas and the marine environment, as well as the overexploitation of fisheries resources, is a global problem.

3) ASSESSMENT:

Student assessments will measure how well the aims of the course have been realised. Assessment results will also suggest which students have aptitudes for particular areas of tertiary study. Student assessments may be a mixture of practical assessments (eg. reports of field excursions), researched project assignments and examinations.

Most sections in this book include practical exercises, assignments and sample questions for students. At advanced levels of education, these should be extended to include assessments of skills in debating and problem solving. Students could then be assessed on their ability to recognise environmental problems and suggest solutions, requiring a range of analytical skills beyond that of technical knowledge alone.

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GLOSSARY OF TECHNICAL TERMS

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

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

Biodiversity (Biological Diversity): The variety of living material in terms of genes, species and ecosystems within a given area.

Biomass: The sum of weights of individuals in a fish stock.

BOD: Biological Oxygen Demand - measure of the amount of pollution in the form of organic material in water; the greater the demand for oxygen, the more polluted the water.

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

Bycatch: The part of the catch which is taken incidentally to the target species, and of which some (trash fish) may be discarded.

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

Carnivore: An organism which eats animals.

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

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

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

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

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

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

Ecologically Sustainable Development (ESD): Use of the environment which aims to meet present needs without compromising the ability of future generations to have the same privilege; development based on the sustainable use both of species and ecosystems, the maintenance of essential ecological processes, and the preservation of biological diversity.

Escape gap: A gap built into a trap or net to allow the escapement of small individuals.

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

Extinction: The total disappearance of a species.

Fisheries extension: Working with the community to provide, or to build on, skills and knowledge to achieve particular goals, such as an increase in seafood production, or the conservation of fish stocks and the environment.

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

Fishing mortality: The death of fish caused by a fishing operation.

Growth overfishing: A level of fishing in which young recruits entering the fishery are caught before they grow to an optimum marketable size.

Herbivore: An animal which eats plant material.

Individual Transferable Quota (ITQ): A catch limit or quota allocated to an individual fisher, who then has a guaranteed share (which may be either harvested or traded) of the total allowable catch of a particular resource species.

Input controls: Limitations on the amount of fishing effort; restrictions on the number, type and size of fishing vessels or fishing gear, or on the fishing areas or fishing times in a fishery.

Integrated Coastal Management (ICM): Coastal management which takes into account the inter-dependence of ecosystems, with the involvement of many different agencies (for example, those responsible for agriculture, forestry, fisheries, public works and water supply).

Joint ventures: A partnership between foreign and local fishers,

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

Licence Limitation: The restriction of fishing to those people, fishing units or vessels holding licences in a limited entry fishery.

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

Maximum Economic Yield (MEY): The yield above which the revenue generated by a marginal increase in effort is less than the cost of that increase; the point at which profits earned in excess of those needed to cover all fishing costs is maximised.

Maximum Sustainable Yield (MSY): The largest annual catch that may be taken from a stock continuously without affecting the catch of future years; a constant long-term MSY is not a reality in most fisheries, where stock sizes vary with the strength of year classes moving through the fishery.

Minimum Legal Size: A regulation in which captured individuals smaller than a prescribed minimum size must be returned to the sea; usually justified on the grounds that growth of smaller individuals produces a greater harvestable biomass, and that the size of the spawning stock is increased.

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

Natural mortality: The death of fish by natural causes, including predation (being eaten by another animal).

Nutrients: In the context of this booklet, dissolved food material (mainly nitrates and phosphates) used by plants.

Open Access Fishery: A fishery with no restriction on the number of fishers or fishing units; an unmanaged fishery.

Output controls: Limitations on the weight of the catch (a quota), or the allowable size, sex, or reproductive condition of individuals in the catch.

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

Pelagic: Living in the surface layers of the sea.

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

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

Predator: An animal which hunts another (prey) species.

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

Quota: A limit on the weight of fish which may be caught in a particular stock or area; a bag limit is a quota (usually in numbers of fish caught) applied to recreational fishers.

Recruitment overfishing: A level of fishing in which the adult stock is reduced to the extent that recruits produced are insufficient to maintain the population.

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

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

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

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

Target species: The resource species at which a fishing operation is directed.

Technology creep: A gradual increase in the efficiency of fishing gear and methods, which results in an increase in effective fishing effort.

Tentacles: The "arms" which surround the mouth of a coral polyp and other animals, such as an octopus.

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

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

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